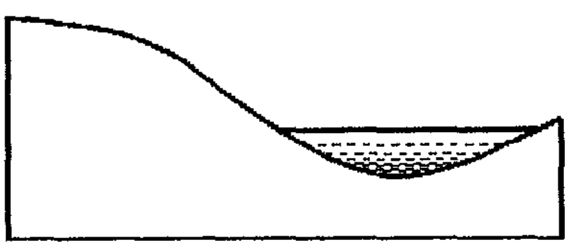
Turkey Flat, USA

Site Effects Test Area

REPORT 3

Weak-Motion Test: Prediction Criteria and Input Rock Motions



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TECHNICAL REPORT NO. 89-1

CALIFORNIA DEPARTMENT OF CONSERVATION

DIVISION OF MINES AND GEOLOGY

EARTHQUAKE SHAKING ASSESSMENT UNIT

Dr. J. Carl Stepp (Chairman)
Electric Power Research Institute

Dr. C.Y. Chang
Geomatrix Consultants, USA

Dr. Neville C. Donovan
Dames & Moore, USA

Mr. James H. Gates
California Department of Transportation, USA

Dr. I.M. Idriss
Woodward-Clyde Consultants, USA

Dr. William B. Joyner
U.S. Geological Survey, USA

Dr. Marshall Lew
LeRoy Crandall and Associates, USA

Mr. Maurice S. Power
Geomatrix Consultants, USA

Mr. Charles R. Real
California Department of Conservation, USA

Mr. Bruce Redpath
Qest Consultants, USA

Dr. Wolfgang Roth
Dames & Moore, USA

Dr. Anthony F. Shakal
California Department of Conservation, USA

Dr. Jogeshwar P. Singh
Geospectra, USA

Dr. Brian E. Tucker
California Department of Conservation, USA

Mr. John Vrymoed
California Department of Transportation, USA

Turkey Flat, USA
Site Effects Test Area

OVERVIEW

NEEDS The 1985 Mexico City earthquake is our most recent reminder that local ground conditions can have a strong influence on where damage will occur in urbanized areas during an earthquake, and underscores the need to incorporate seismic shaking potential in land-use decisions. Although several different methods for making such assessments are currently in use, their accuracy and costs are not well known. Reliability and cost of methods must be known before they can be routinely used to provide a sound basis for safer land-use and construction practices.

GOALS The principal goals of the Turkey Flat Site Effects Test Area are to systematically compare and determine the reliability of contemporary methods used to estimate the effect of local geology on earthquake shaking, and to test the linearity of shallow stiff-soil site response.

OBJECTIVES Principal objectives are to collect high quality weak- and strong-motion data at several locations in the test area produced by local and regional earthquakes, quantify the site geology in terms of its geotechnical properties, and distribute the information to experts around the world.

APPROACH Using the acquired data, a series of "blind" predictions will be made by ground motion experts for test area locations where the response will be known, but not be available until all predictions have been received. Results of each prediction will be compared with one another and with actual observed ground motion.

PRODUCTS A series of reports describing each principal phase of the project will be available as the work progresses. An evaluation of all site response estimation methods will be prepared with recommendations as to suitability and cost of routine application for urban earthquake shaking hazard assessment.

Acknowledgments

Special recognition is due the following agencies, companies and corporations for their support and advice: California Department of Transportation, Dames & Moore, Electric Power Research Institute, Geomatrix Consultants, Geospectra, Harding Lawson Associates, Kajima Corporation, LeRoy Crandall Associates, OYO Corporation, Pitcher Drilling Company, Redpath Geophysics, U.S. Geological Survey, and Woodward-Clyde Consultants. We also wish to thank the California Department of Conservation's Strong-Motion Instrumentation Program for assistance in processing the test data, and Lawrence Livermore National Laboratory for loan of field recording equipment. We also thank Michael Reichle of the California Department of Conservation's Division of Mines and Geology for assistance in developing appropriate instrument corrections.

Most of all, we are grateful for the cooperation of Donald and Nila McCornack, owners of the land on which the Turkey Flat array is located.

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FOREWORD

IASPEI/IAEE Joint Working Group

At the 1985 meeting of the International Association of Seismology and Physics of the Earth's Interior (IASPEI), held jointly with the International Association of Earthquake Engineering (IAEE) in Tokyo, Japan, a resolution was passed forming the IASPEI/IAEE Joint Working Group on The Effects of Local Geology on Seismic Motion. The purpose of this group is to coordinate the establishment of an international series of test areas designed to provide a data base for comparing and testing contemporary methods, and developing new methods, to predict the effects of local geology on ground motion caused by earthquakes. The 1985 Mexico earthquake is only the most recent reminder that local ground conditions can have a major influence on where damage will occur in major earthquakes. Although methods for assessing site effects are being used to construct critical facilities around the world, the reliability of these methods has not been rigorously tested. It is the goal of this international program to fulfill this need. An international program provides a forum for experts around the world to exchange ideas, and significantly increases the prospects of acquiring the necessary data soon.

Turkey Flat Experiment

The California Department of Conservation's Division of Mines and Geology (DMG) has, among other mandates, the responsibility to look after the interest of the State and its people with regard to seismic and geologic hazards and promote safe utilization of the state's terrain. Safety analyses of critical facilities such as nuclear power plants, liquid natural gas repositories, and hospitals, as well as provision of hazard information to local governments for planning and development, require application of state-of-the-art techniques in predicting ground motion expected from future earthquakes; however, contemporary methods have not been thoroughly validated. When asked why microzonation has not been implemented in the U.S., the answer is often: "If you ask ten different experts how the ground might shake at a specific site during an earthquake, you will get ten different answers". We see a strong need to identify those methods that are reliable and those that are not, and to establish guidelines and procedures that insure repeatability, in order to effectively carry out our mandates. As a consequence, we have established a test area at Turkey Flat, California where a series of experiments will help answer this need.

Our general perceptions and experiment objectives echo those of

IASPEI/IAEE's Joint Working Group. In their first workshop, held during the XIX Assembly of the International Union of Geodesy and Geophysics in Vancouver, British Columbia, Canada in August of 1987, a resolution was passed incorporating the experiment at Turkey Flat into the international program.

The principal objectives of the Turkey Flat Experiment are to systematically test and compare all methods of estimating the influence of local geology on ground motion during earthquakes, in order to determine the reliability and cost effectiveness of each. Secondary objectives are to generate a data base for the improvement of these methods, or the development of new methods, and to address the long standing debate on the linearity of site response. The approach is to collect high quality weak and strong ground motion data, and geotechnical data, and carry out a series of "blind predictions". Experts from around the world are invited to use their preferred method and the acquired data to predict ground motion at locations where the actual response will be known but held in confidence until all predictions have been submitted.

The experiment is being conducted in a number of phases, and this report constitutes the results of phase III, Weak-Motion Data Acquisition. A more detailed description of the overall experiment is provided in Report 1, <u>Turkey Flat, USA, Site Effects Test Area: Needs, Goals and Objectives</u>. A detailed description of the local site geology and geotechnical properties is provided in Report 2, Turkey Flat, USA, Site Effects Test Area: Site Characterization.

This report is organized in three principal parts: 1) Prediction Criteria, which describes the predictions that participants are requested to make and provides a schedule for their completion, 2) Input Rock Motions, which describes the input and output formats of data files and plots, presents instrument and array characteristics, and describes the data collection and processing procedures employed, and 3) a series of appendices that contain detailed descriptions and examples of data formats, and a Standard Geotechnical Model for the test site.

TURKEY FLAT, USA, SITE EFFECTS TEST AREA
PREDICTION CRITERIA

INTRODUCTION

This part of the report describes the weak-motion site effects prediction test for the Turkey Flat, USA, Site Effects Test Area, and includes the prediction criteria determined by a committee of experts (see inside cover), and a test schedule. Input ground motion data, formats of input and requested output, and background details on acquisition and preparatory processing of the test data are discussed in Part 2 of this report. In addition to this report, participants should also have: a) an additional report that describes the geotechnical properties of the test area, b) digital data files of weak ground motion recorded spring 1988 at the Rock South (R1) array site at Turkey Flat, and c) data files of ground motion recorded at the Temblor strong-motion station during the 1966 Parkfield Earthquake. Together with this plan, these data are sufficient to estimate ground motions recorded at other array sites using participant-supplied methods.

As described below, several ground-motion estimates are requested to be made given these data. They will be made for sites where the actual ground motion has been recorded, but the records are being kept in confidence until all prediction estimates have been received. Consequently, the tests are "blind predictions" whereby methods of estimating the effects of local site geology will be tested without prior knowledge of the actual effects. When all predictions have been received, participant results will be compared with one another and with actual recorded ground motions at each site.

WEAK-MOTION TEST

Instrument Array

A schematic cross-section of the Turkey Flat array is shown in figure 1. The array is composed of seven sensors indicated by solid black circles having accompanying alphanumeric identification codes beginning with a letter corresponding to R (rock), V (valley), and D (downhole). All predictions that are requested to be made will reference sensor locations by these codes. Each sensor location consists of three-component velocity-type transducers which are described in detail in Part 2 of this report.

Site names have been given to each surface instrument location: Rock South (R1), Valley Center (V1), Valley North (V2), and Rock North (R2). Dynamic soil properties are referred to by these site names in Report 2: Turkey Flat, USA, Site Effects Test Area: Site Characterization. For convenience, the Standard Geotechnical Model developed in Report 2 is reproduced in Appendix D of this report.

GROUND MOTION PREDICTION PLAN

I. Instrument Layout:

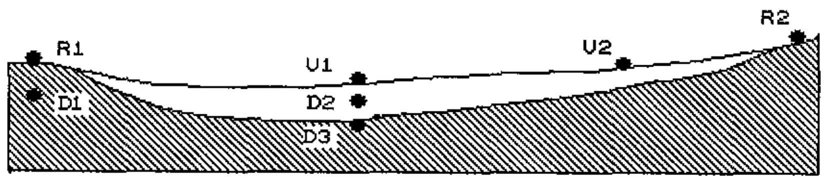


Figure 1

II. Ground Motion Predictions:

Table 1. Weak-Motion and optional arbitrary strong-motion tests:

Prediction	Required [1]	Optional [2]
1. Fourier Amplitude Spectral Ratios.	1) Xi/R1 given R1 (where Xi means D1,D2,D3,V1,V2,R2). 2) V1/D3, D2/D3 given D3.	1) Xi/R1 given R1 (where Xi means D1,D2,D3,V1,V2,R2).
2. Acceleration Time-Histories.	1) V1 given R1. 2) V1 given D3.	1) V1 given R1.
3. Psuedovelocity Response Spectra (5% damped), and peak values of velocity, acceleration, & displacement.	1) Xi given R1 (where Xi means D1,D2,D3,V1,V2,R2). 2) V1,D2 given D3.	1) V1,D2,D3 given R1.

1 Predictions must be done using the standard model, and can optionally be done for a participant-provided preferred model. Only horizontal components of motion are requested.

2 Participant given largest horizontal component of the Temblor station record of 1966 Parkfield Earthquake.

III. Schedule:

Table 2

Date	Activity
3/15/89	Responses to invitation received
5/89	DMG distributes R1
9/1/89	Predictions due DMG
9/15/89	D3 distributed
12/1/89	Predictions due DMG
12/15/89	Distribute observations
Spring 90	Workshop
	Publications

Ground Motion Predictions

The primary goal of the Turkey Flat experiment is to test methods of estimating the effects of local site geology on damaging levels of ground motion. Ultimately, we must await occurrence of the anticipated Parkfield Characteristic earthquake before a robust test of methods can be made; however, the Weak-Motion group of tests will contribute to the goal by providing: 1) a scheduled product, 2) a means of setting up and testing ground-motion prediction models and procedures for readiness when the anticipated Parkfield Characteristic Earthquake occurs, 3) a means of testing how well the dynamic soil characteristics of the test area have been determined, and eventually 4) an opportunity to compare very low strain predictions and observations with those at high levels of strain, which bears on the question of linearity of ground motion and its relevance to microzonation.

Required Predictions

Table 1 shows the REQUIRED and OPTIONAL ground motion predictions to be made in three general forms: 1) Fourier Amplitude Spectral Ratios, 2) Acceleration Time Histories, and 3) 5% Damped Pseudovelocity Response Spectra. We also request that Peak Values of Acceleration, Velocity, and Displacement be provided. To participate fully in the experiment one must compute, for each horizontal component, all of the items for each form of prediction listed under the column titled REQUIRED using the Standard Geotechnical Model and instrument corrected acceleration time histories for the specified event. The requested predictions consist of 36 plots in all.

A Standard Geotechnical Model is provided in order to facilitate comparison of prediction methods, since each prediction will use the same geotechnical model and same input motions. Because predictions will be compared among themselves and with actual recordings, some participants may want to use a different geotechnical model for the latter comparison. Those that do can develop a Preferred Geotechnical Model from the basic data contained in Report 2. Participants who wish to specify site characteristics more accurately should do so and submit a complete set of predictions based on their preferred model. This would result in an additional 36 plots, yielding a total of 72 plots.

Optional Ground Motion Test: Arbitrary Strong-Motion Record

Entirely optional, and at full discretion of the participant, is a group of tests using input from an arbitrary strong-motion record. This is to be done at the same time as the Weak-Motion Test, and might be useful when setting up and testing models that incorporate non-linear behavior of soils at higher levels of strain.

Under heading OPTIONAL of Table 1 are the optional tests based on input motions from the larger horizontal component of the 1966 Parkfield earthquake Temblor station record. The three forms of predictions specified previously are requested, but within each form there are no prediction items based on inputs from site D3 since an arbitrary surface record from outside the array is used. While these tests are not true predictions, they will serve as a benchmark, and should, therefore, be made using the Standard Geotechnical Model to facilitate comparison. This will yield a total of 10 plots for the optional tests.

Submittals

Participants are requested to submit all results in two forms: 1) paper plots, and 2) digital data files on computer readable media (9-track tape or IBM compatible 360K 5 1/4 in. floppy disks). Standard formats for each are described in Part 2 of this report.

SCHEDULE

Table 2 outlines the schedule and procedure to be followed for the Weak-Motion Tests. Included with this report are records for the weak-motion test event recorded at R1 (rock south site), and an instrument corrected horizontal component of motion from the 1966

Parkfield earthquake recorded at the Temblor station. *Predictions based on R1 input motions are due* **September 1, 1989,** *and must be postmarked no later than this date to be considered a valid "blind" prediction.*

On **September 15, 1989**, after all predictions based on the records at site R1 have been received, records at site D3 will be distributed. At this time, participants will be able to compare their predicted motions at site D3 with actual recorded motions. *Predictions based on D3 input motions are due* **December 1, 1989,** *and must be postmarked no later than this date to be considered a valid "blind" prediction.*

On **December 15, 1989**, after all predictions based on the records at site D3 have been received, actual recorded ground motions at all array sites will be distributed to participants for analysis of observed and predicted ground motions. A workshop will then be scheduled **Spring 1990** where findings can be shared and discussed, and insights can be used to optimize predictions to be made in the final phase involving the Parkfield Characteristic Earthquake. It is anticipated that several publications will result from the Weak-Motion Test.

While the Weak-Motion Test is important in its own right, the essence of this experiment is testing contemporary methods of predicting site effects on ground motions capable of causing damage to engineered structures. The ultimate test, then, must await occurrence of the anticipated Parkfield Characteristic Earthquake. While the Strong-Motion Test cannot be rigorously scheduled until after the occurrence of this event, data will be distributed according to a schedule similar to the Weak-Motion Test schedule, with the same predictions being requested. Consequently, the Strong-Motion Test should run more smoothly and efficiently when the time comes. These plans, however, are tentative as modifications might occur as a result of experience gained from the Weak-Motion Test.

TURKEY FLAT, USA, SITE EFFECTS TEST AREA

INPUT ROCK MOTIONS

INTRODUCTION

This part of the report describes the input rock motion data files for the Weak-Motion Test and is divided into two sections. The first section presents the *required* rock input record (R1) and the *optional* rock input record, and describes standard plot and data file formats for all test input and output. The second section describes the weak-motion array and instrumentation, and discusses the data processing applied to the weak-motion data. Detailed information on data formats is provided in Appendices A through C.

Because examples of the input rock motions are provided in this part of the report, it is convenient to use them as examples of the format required from all participants for all output. Having a standard format for prediction results will greatly facilitate comparisons during analysis. Consequently, formats for all data input and output in this experiment are presented here.

INPUT ROCK MOTIONS AND DATA FORMATS

Input Rock Motion Record R1

A weak-motion record from the Rock South site at Turkey Flat is provided as the mandatory bedrock input record for predicting the low strain response across the Turkey Flat, USA, strong motion array (figure 2). The source event for this record is a magnitude 2 earthquake located approximately 34 km north of the test area (exact location is provided in file headers). All three components of bedrock motion are provided even though only the two horizontal components (figure 3) will be use in making predictions. *The units of weak-motion acceleration are* 10^{-6} *m/sec/sec.* Details about recording equipment, data processing, and instrument corrections are discussed subsequently.

Optional 1966 Parkfield Record

A record from the 1966 Parkfield earthquake is provided as an optional bedrock input record for predicting strong ground motion across the Turkey Flat, USA, site. The S25W (South) component of the Temblor 2 record (figure 4) has been chosen as the optional bedrock record for this test. The record has been instrument and baseline corrected and is sampled at 50 samples per second (sps) (CIT-EERL, 1973). *The units of strong-motion acceleration are cm/sec/sec.*

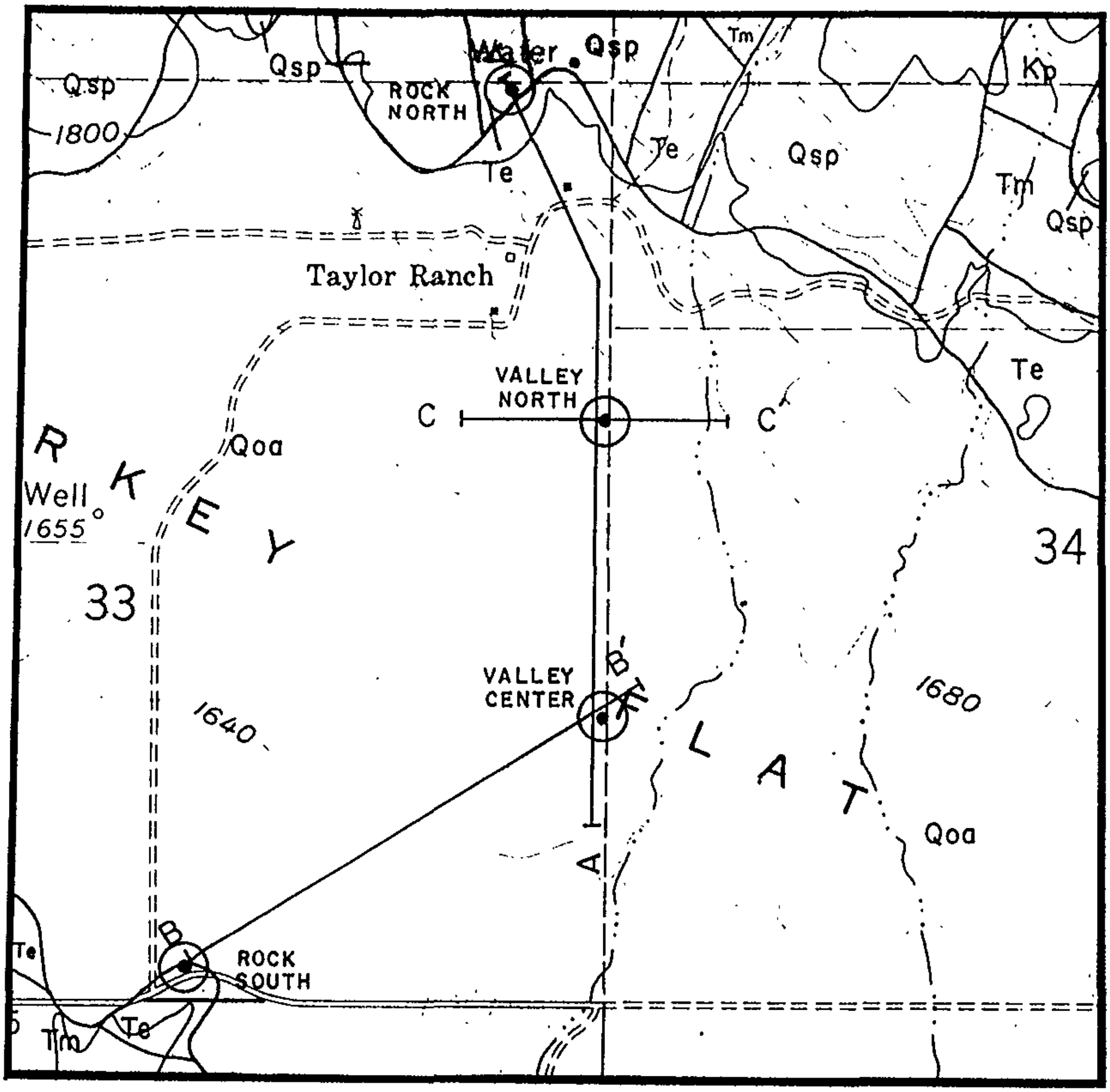


Figure 2. A map of the Turkey Flat Site Effects Test Area showing locations of the four ground motion recording sites, and three lines of profile that correspond to the cross sections shown in figure 11.

Figure 3: Standard Time History Accelerogram:
Station R1 Standard Geotechnical Model Accelerograms

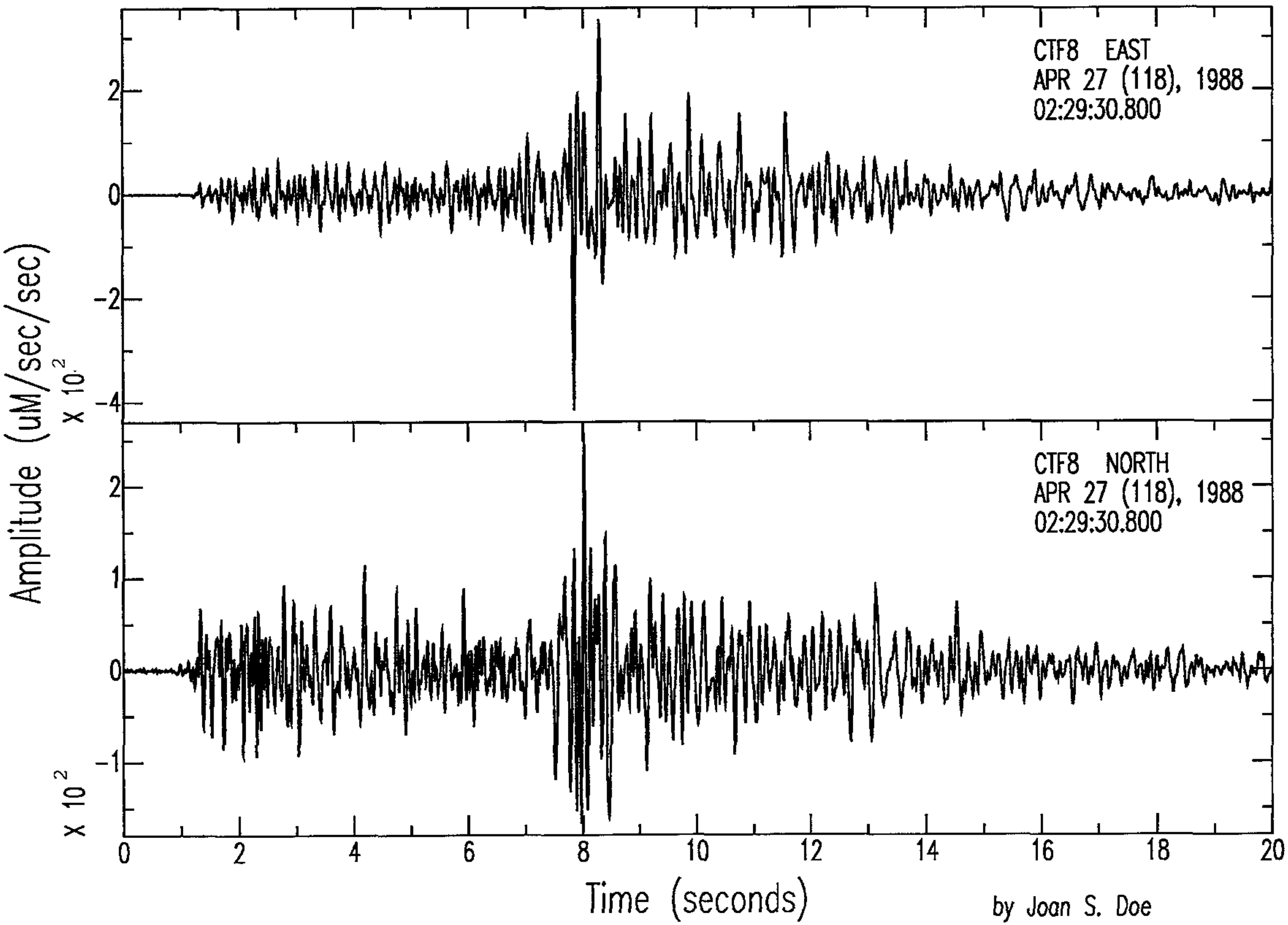
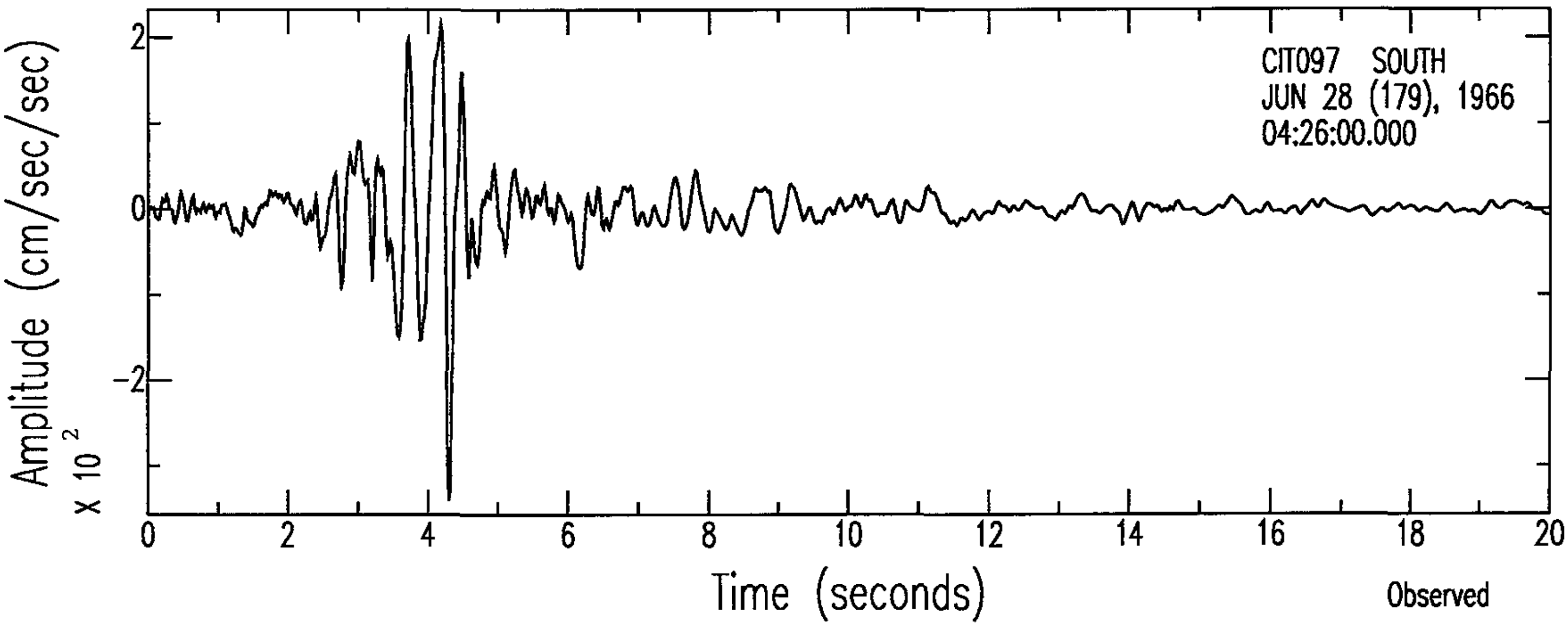


Figure 4: Temblor 1966 Accelerogram



Standard Input/Output Data Formats

Input ground motions and predicted ground motions are in three different forms as discussed in Part 1: 1) Fourier amplitude spectral ratio, 2) time history, and 3) response spectrum. Each form has a corresponding data file and plot format. Participants are required to return paper plots of results in each of the three standard plot formats so that predictions can be directly overlaid on actual observations for comparison. Participants are also requested to return prediction results on computer readable media in the three standard data file formats to facilitate statistical comparisons and help summarize experiment results. *The original media containing the input data files can be used for this purpose.* Upon receipt of results, the same media will again be used to provide actual recorded ground motions at site D3 to participants for input in the second part of the test, and again to distribute results for all the sites after all predictions have been received.

File Formats

The three standard computer-readable data-file formats used in the prediction experiment conform to California Strong Motion Instrumentation Program (CSMIP) standards (Shakal and Huang, 1985). They are described as follows.

Time Histories - will be in CSMIP Volume 2 format. Appendix A contains the standard for Volume 2 from Shakal and Huang (1985) plus an example for R1. Although velocity and displacement will be computed in the course of determining peak values, *only acceleration time history data files are requested to be provided.*

Response Spectra - will be in an abbreviated CSMIP Volume 3 format, hereafter referred to as the Response Spectra (RS) format. Appendix B contains the RS format standard which has been modified from Shakal and Huang for this experiment by retaining only the header array, sample periods array, and the 5% damped psuedovelocity response spectrum array. Response spectral values will be computed at the standard periods listed in Appendix B. Real-Header elements 66, 68, and 70 should contain peak acceleration, peak velocity, and peak displacement respectively, even though the time history files are not requested for all sites. An example for R1 is also included in Appendix B.

Fourier Amplitude Spectral Ratio - There is no CSMIP standard for this output form, so a standard for this experiment has been devised that conforms with the Volume 2 and 3 standards. Appendix C contains a description of the chosen Fourier amplitude spectral ratio (FSR) standard plus an example for R1. Fourier spectra should be smoothed before calculating ratios. Smoothing should be equivalent to a 1 Hz running-mean window passed twice over the individual spectra.

Data files received by participants will conform to these three standards with the exception of: 1) the inclusion of the word "OBSERVED" in columns 45-52 of Text Header 6 of Volume 2 files (hence in columns 45-52 of Text Header 7 of RS and FSR files), and 2) the unit of length for weak-motion time history and response spectrum files will be 10^{-6} meters (um) instead of centimeters (see Examples A-C).

Data files returned by participants shall also conform to these three standards and additionally put: 1) the words "STANDARD GEOTECHNICAL MODEL" or "PREFERRED GEOTECHNICAL MODEL" in columns 51-80 of Text Header 3 of Volume 2 files (predicted time histories) and Text Header 4 of RS and FSR files (predicted response spectra and spectral ratios), and 2) the words "PREDICTED BY" and your name or identification number in columns 45-80 of Volume 2 Text Header 6 (Text Header 7 for RS and FSR files) (see samples in Appendices A - C).

Plot Formats

To verify the contents of data files and facilitate comparison with observations, participants are required to provide results on three standard paper plots. Both data sent to participants and predictions received from participants should conform to these plot standards. In the event a participant is not able to provide results in digital form, the plots will be the only means of com-

Example A - Sample listing of Volume 2 file sent to experiment participants:

```
CORRECTED ACCELEROGRAM  R1  (CTF8)                          CHAN  1:  90 DEG     FROM  N
UNCORRECTED VELOCITY DATA                               PROCESSED: 05/18/88, CDMG EVENT12
TURKEY FLAT, USA, WEAK-MOTION TEST EVENT
APRIL 26, 1988 18:29 PST                         (ORIGIN(USGS):  4/27/88,   2:29:25.29GMT)
WEAK-MOTION EVENT 12                     TRIGGER TIME:  4/27/88,  2:29:30.80GMT
STATION NO. CTF8    35.878N, 120.361W     DR100  S/N  151 ( 3 CHNS OF  3 AT STA)
TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)     OBSERVED
CHAN  1:  90 DEG  (STA CHN:  3)
COALINGA AREA EARTHQUAKE
HYPOCENTER(USGS): 36.183N,120.329W, H= 4KM.  ML=2.0(USGS).
INSTR PERIOD = 0.50   SEC,  DAMPING =  0.6 ,  SENSITIVITY = 104. V/M/S
                        RECORD LENGTH =  28.72 SEC.
                                     UNCOR MAX  =         G, AT         SEC.
RMS ACCEL OF (UNCOR) RECORD  =        G.
TWO POLE BUTTERWORTH BANDPASS FILTERED WITH CORNERS AT  1 AND 20 HZ.
  2873 POINTS OF INSTRUMENT- AND BASELINE-CORRECTED ACCEL                    DATA
AT EQUALLY-SPACED INTERVALS OF   0.010  SEC.
PEAK ACCELERATION =  -415.426    uM/SEC/SEC  AT      7.840  SEC.  (uM=10**-6M)
PEAK    VELOCITY   =      9.047      uM/SEC     AT      7.870  SEC.
PEAK DISPLACEMENT =    -0.3527       uM       AT    10.770  SEC.
INITIAL VELOCITY  =     0.0074  uM/SEC;   INITIAL DISPLACEMENT =   -0.00173 uM
COALINGA AREA EARTHQUAKE

WEAK-MOTION EVENT 12, TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)   CHAN  1:  90 DEG

    1    1    1    3    3    0    1    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0   90 2873   40   40   25    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0 2873 2873 2873    0    0    0    0    0   25   80    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0
     0.500     0.600    28.720     0.000     0.000     0.000     0.000     0.000
     2.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000    12.566     0.000
     0.000     0.000     0.000     0.000     0.010     0.000     0.000     0.000
     7.840  -415.426     7.870     9.047    10.770    -0.353     0.007     0.000
     0.000     0.000    -0.002     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000
 2873 POINTS OF ACCEL DATA EQUALLY SPACED AT 0.010 SEC.  (UNITS: uM/SEC/SEC)
    -0.290     0.754     0.601     0.106    -0.012     0.031     0.084     0.101
     0.079     0.116    -0.049    -0.691    -0.290     0.753     0.582     0.130
    -0.158    -0.749    -0.398    -0.185    -0.531     0.230     0.391     0.027
    -0.140     0.045     0.665     0.486    -0.117    -0.854    -0.361     0.563
        ...
        ... (Remainder of acceleration data) ...
        ...
/&    <----- (End of data for this channel)
        ...
        ... (Header, etc for next channel)
        ...
        ...
```

Example B - Sample listing of Response Spectra file sent to experiment
            participants:

```
RESPONSE AND FOURIER AMPLITUDE SPECTRA (51 PERIODS,  .04 -  1.0 SEC)    FOR
CORRECTED ACCELEROGRAM  R1 (CTF8)                     CHAN  1:  90 DEG     FROM  N
UNCORRECTED VELOCITY DATA                     PROCESSED: 05/18/88, CDMG EVENT12
TURKEY FLAT, USA, WEAK-MOTION TEST EVENT
APRIL 26, 1988 18:29 PST                  (ORIGIN(USGS):  4/27/88,  2:29:25.29GMT)
WEAK-MOTION EVENT 12                 TRIGGER TIME:  4/27/88,  2:29:30.80GMT
STATION NO. CTF8    35.878N, 120.361W    DR100  S/N  151 ( 3 CHNS OF  3 AT STA)
TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)     OBSERVED
CHAN  1:  90 DEG  (STA CHN:  3)
COALINGA AREA EARTHQUAKE
HYPOCENTER(USGS): 36.183N,120.329W, H= 4KM.  ML=2.0(USGS).
INSTR PERIOD = 0.50   SEC,  DAMPING =  0.6 ,  SENSITIVITY = 104. V/M/S
                        RECORD LENGTH =  28.72 SEC.
                                   UNCOR MAX  =          G, AT          SEC.
RMS ACCEL OF (UNCOR) RECORD  =       G.
TWO POLE BUTTERWORTH BANDPASS FILTERED WITH CORNERS AT  1 AND 20 HZ.
                 INSTRUMENT- AND BASELINE-CORRECTED




COALINGA AREA EARTHQUAKE

WEAK-MOTION EVENT 12, TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)   CHAN  1:  90 DEG

WEAK-MOTION EVENT 12, TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)   CHAN  1:  90 DEG

UNITS FOR PSEUDOVELOCITY SPECTRUM IS uM/SEC.

    1    1    1    3    3    0    1    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0   90 2873   40   40   25    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0 2873 2873 2873    0    0    0    0    0   25   80    0    0    0    0
    0    0   81   51    5    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0
     0.500     0.600    28.720     0.000     0.000     0.000     0.000     0.000
     2.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000    12.566     0.000
     0.000     0.000     0.000     0.000     0.010     0.000     0.000     0.000
     7.840  -415.426     7.870     9.047    10.770    -0.353     0.007     0.000
     0.000     0.000    -0.002     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000
     0.050
     0.040     0.042     0.044     0.046     0.048     0.050     0.055     0.060
     0.065     0.070     0.075     0.080     0.085     0.090     0.095     0.100
        ... (Remainder of 100 element period array) ...
DAMPING =  .05. DATA OF PSSV  :
 0.300e+01 0.323e+01 0.338e+01 0.353e+01 0.373e+01 0.406e+01 0.493e+01 0.574e+01
        ... (Remainder of 100 element pseudovelocity array) ...
/&    <----- (End of data for this channel)
        ...
        ... (Header, etc for next channel)
        ...
```

Example C - Sample listing of Fourier Sectral Ratio file sent to participants:

```
SPECTRAL RATIO WITH RESPECT TO REFERENCE STATION  R1 (CTF8)                 FOR
CORRECTED ACCELEROGRAM  R1 (CTF8)                      CHAN  1:  90 DEG    FROM  N
UNCORRECTED VELOCITY DATA                     PROCESSED: 05/18/88, CDMG EVENT12
TURKEY FLAT, USA, WEAK-MOTION TEST EVENT
APRIL 26, 1988 18:29 PST                (ORIGIN(USGS):  4/27/88,  2:29:25.29GMT)
WEAK-MOTION EVENT 12                 TRIGGER TIME:  4/27/88,  2:29:30.80GMT
STATION NO. CTF8    35.878N, 120.361W    DR100  S/N  151 ( 3 CHNS OF  3 AT STA)
TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)     OBSERVED
CHAN  1:  90 DEG  (STA CHN:  3)
COALINGA AREA EARTHQUAKE
HYPOCENTER(USGS): 36.183N,120.329W, H= 4KM.  ML=2.0(USGS).
INSTR PERIOD = 0.50   SEC,  DAMPING =  0.6 ,  SENSITIVITY = 104. V/M/S
                        RECORD LENGTH =  28.72 SEC.
                                     UNCOR MAX  =         G, AT         SEC.
RMS ACCEL OF (UNCOR) RECORD  =       G.
TWO POLE BUTTERWORTH BANDPASS FILTERED WITH CORNERS AT  1 AND 20 HZ.
FFT COMPUTED FROM WINDOW STARTING AT  6.741  SEC AND ENDING AT  14.741 SEC.
AMPLITUDE SPECTRA OF STATION AND REFERENCE SMOOTHED 2 TIMES
WITH A 11 POINT RUNNING MEAN FILTER BEFORE FORMING SPECTRAL RATIO.
SPECTRAL RATIO DATA BEGINS AT  1.000 HZ AND ENDS AT 20.000  HZ.
  194 POINTS OF SPECTRAL RATIO DATA AT EQUALLY-SPACED INTERVALS OF 0.09766  HZ.
COALINGA AREA EARTHQUAKE

WEAK-MOTION EVENT 12, TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)   CHAN  1:  90 DEG

    1    1    1    3    3    0    1    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0   90 2873   40   40   25    0
    0    0    0    0    0    0    0    1    0    0    0    0    0    0    0    0
    0    0 2873 2873 2873    0    0    0    0    0   25   80    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0
     0.500     0.600    28.720     0.000     0.000     0.000     0.000     0.000
     2.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000    12.566     0.000
     0.000     0.000     0.000     0.000     0.010     0.000     0.000     0.000
     7.840  -415.426     7.870     9.047    10.770    -0.353     0.007     0.000
     0.000     0.000    -0.002     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000
  194 POINTS OF SPECTRAL RATIO DATA EQUALLY SPACED AT 0.09766 SEC (UNITS: RATIO)
     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
         ...
         ... (Remainder of acceleration data) ...
         ...
/&    <----- (End of data for this channel)
         ...
         ... (Header, etc for next channel)
         ...
         ...
```

parison, and hence, must conform to standards. *Please include your name on all plots.*

Time History - Plots are scaled so that: 1) the horizontal axis ranges from 0 to 20 seconds with second marks having 10 mm spacing, and 2) the vertical axis is in 10^{-6} m (cm for strong-motion records) auto-scaled so that the maximum peak-to-peak amplitude is equal to 68 mm for each component (the vertical axis length will be 72 mm which leaves a 2 mm space between each extremum and its corresponding axis limit). Both horizontal components are plotted on a single page. An example for R1 is shown in figure 3.

Response Spectrum - Plot scaling is 47.5 mm/decade logarithmic for both horizontal and vertical axes. The vertical scale is pseudovelocity amplitude in 10^{-6} m/sec (cm/sec for strong-motion records), ranging over three decades. The horizontal axis is period ranging from .06 to 10 seconds (total horizontal axis length is 105 mm). Both components are plotted on a single page. An example for R1 is shown in figure 5.

Fourier Amplitude Spectral Ratio - Plots are scaled: 1) so that the linear horizontal frequency scale ranges from 1 to 20 Hz with 10 mm spacing between 1 Hz divisions, and 2) the logarithmic vertical axis ranges from .1 to 10 in dimensionless units with a spacing of 36 mm per decade. Both components are plotted on a single page. An example for R1 is shown in figure 6.

Figure 5: Standard Response Sprectra:

Station R1 Standard Geotechnical Model Response Spectra

by Joan S. Doe

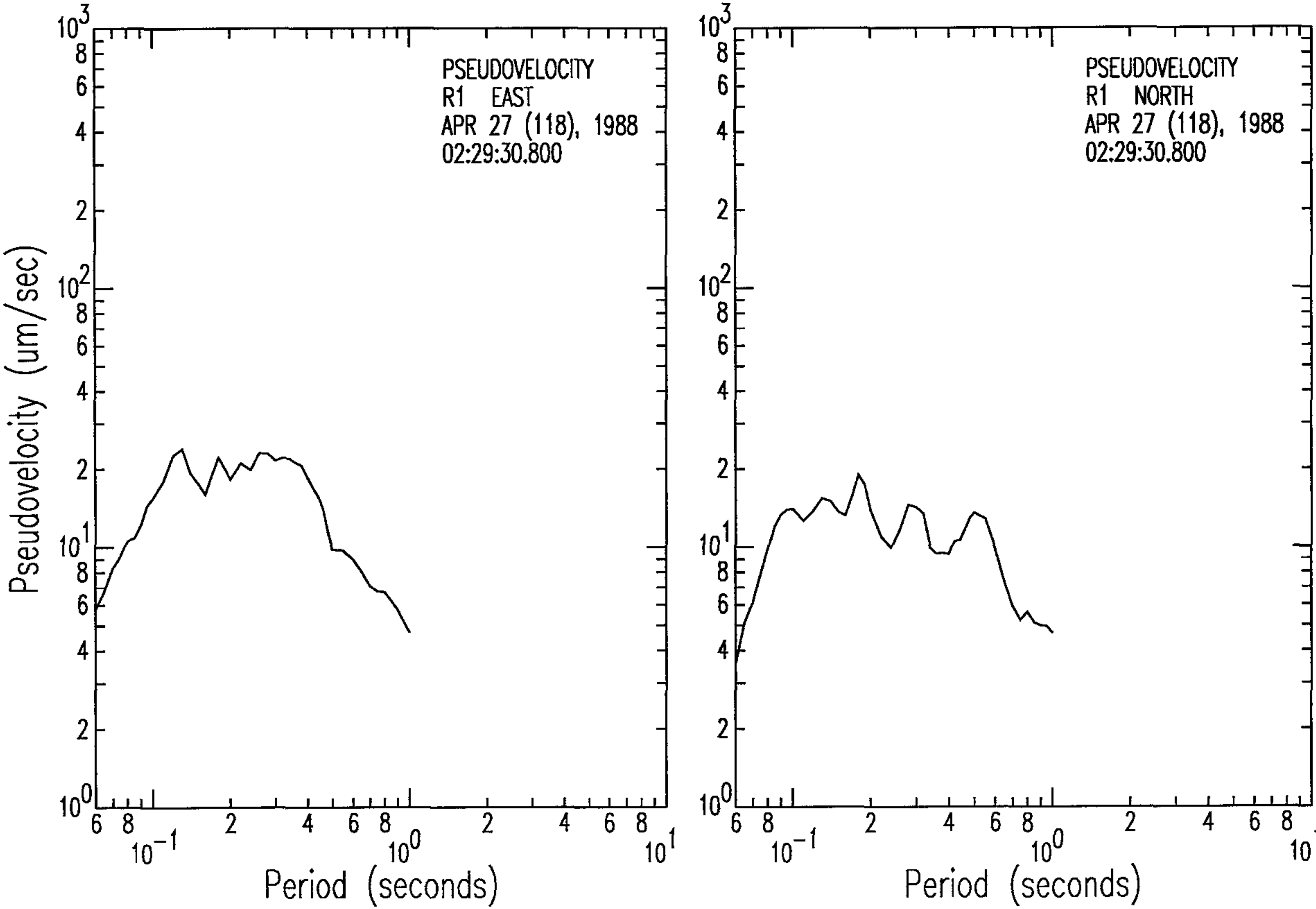
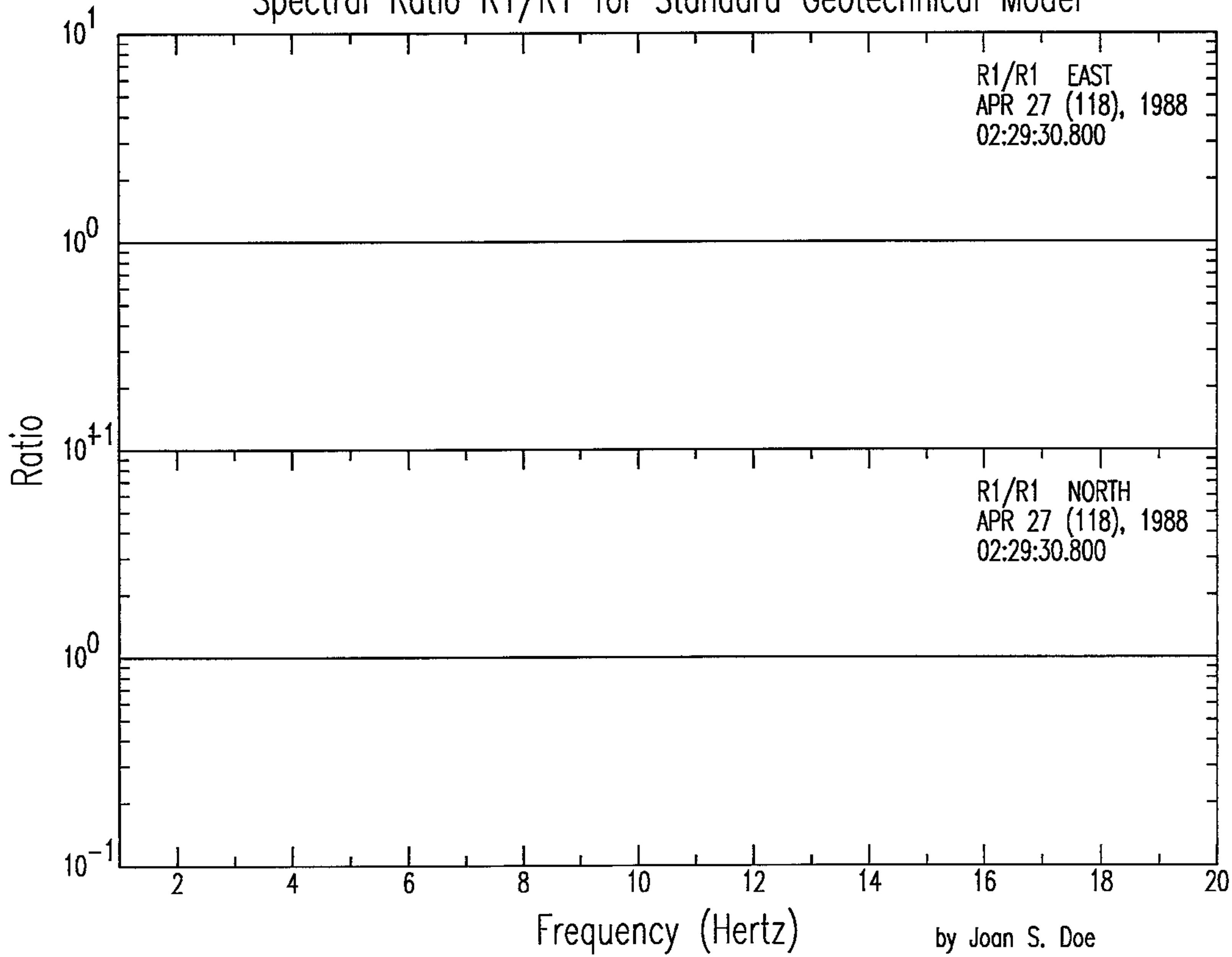


Figure 6: Standard Fourier Spectral Ratio Plot:
Spectral Ratio R1/R1 for Standard Geotechnical Model



by Joan S. Doe

Peak Acceleration, Velocity, and Displacement - Peak values of ground motion parameters are to be provided for the sensor locations indicated in Table 1 of the ground motion prediction plan (see Part 1). The values are to be provided as tables either by copying and filling in the tables shown in figures 7-9, or preparing tables of similar format. Peak values of ground motion parameters are also requested to be included in the RS files (see Response Spectrum file format).

Observed Ground Motions - Actual ground motions recorded at each array station have been instrument corrected, bandpass filtered, and converted to accelerograms as described in a later section. The resulting acceleration time histories were then processed by the California Strong-Motion Instrumentation Program (CSMIP) using routine Volume 2 and 3 procedures, without the usual bandpass filtering, and modified for the low amplitude records. Upon completion of the Weak-Motion Test, processing results for all array sensor location records will be distributed to participants. Examples of the CSMIP processing results for sensor location R1 are provided in Appendix E.

Figure 7. Required Table of Peak Ground Motions for Weak-Motion Recorded at R1 (N=0 Deg, E=90 Deg).

GIVEN INPUT ROCK MOTIONS AT R1				
Sensor Location		Acceleration (um/sec/sec)	Velocity (um/sec)	Displacement (um)
V1	N			
	E			
V2	N			
	E			
D1	N			
	E			
D2	N			
	E			
D3	N			
	E			
R2	N			
	E			

Figure 8. Required Table of Peak Ground Motions for Weak-Motion Recorded at D3 (N=0 Deg, E=90 Deg).

GIVEN INPUT ROCK MOTIONS AT D3				
Sensor Location		Acceleration (um/sec/sec)	Velocity (um/sec)	Displacement (um)
V1	N			
	E			
D2	N			
	E			

Figure 9. Optional Table of Peak Ground Motions for Hypothetical Strong-Motion at R1 (N=0 Deg, E=90 Deg).

GIVEN 1966 PARKFIELD TEMBLOR RECORD AS R1				
Sensor Location		Acceleration (cm/sec/sec)	Velocity (cm/sec)	Displacement (cm)
V1	N			
	E			
D2	N			
	E			
D3	N			
	E			

WEAK-MOTION ARRAY AND DATA PROCESSING

Instrumentation

During the winter and spring of 1988, the California Division of Mines and Geology's (DMG) Earthquake Shaking Assessment Unit deployed a weak-motion array of triaxial velocity transducers at the strong-motion sites at Turkey Flat (see Real, 1988, for site characterization). The array was composed of both surface and downhole seismometers and was first operated in a huddle test mode at the Rock South site and then deployed at the four sites shown in figure 2. Recording was accomplished on three-component digital seismographs connected to and controlled by an array trigger box. Data recorded on magnetic-tape cassettes was taken back to Sacramento and played-back into a computer system for event identification and processing.

Hardware

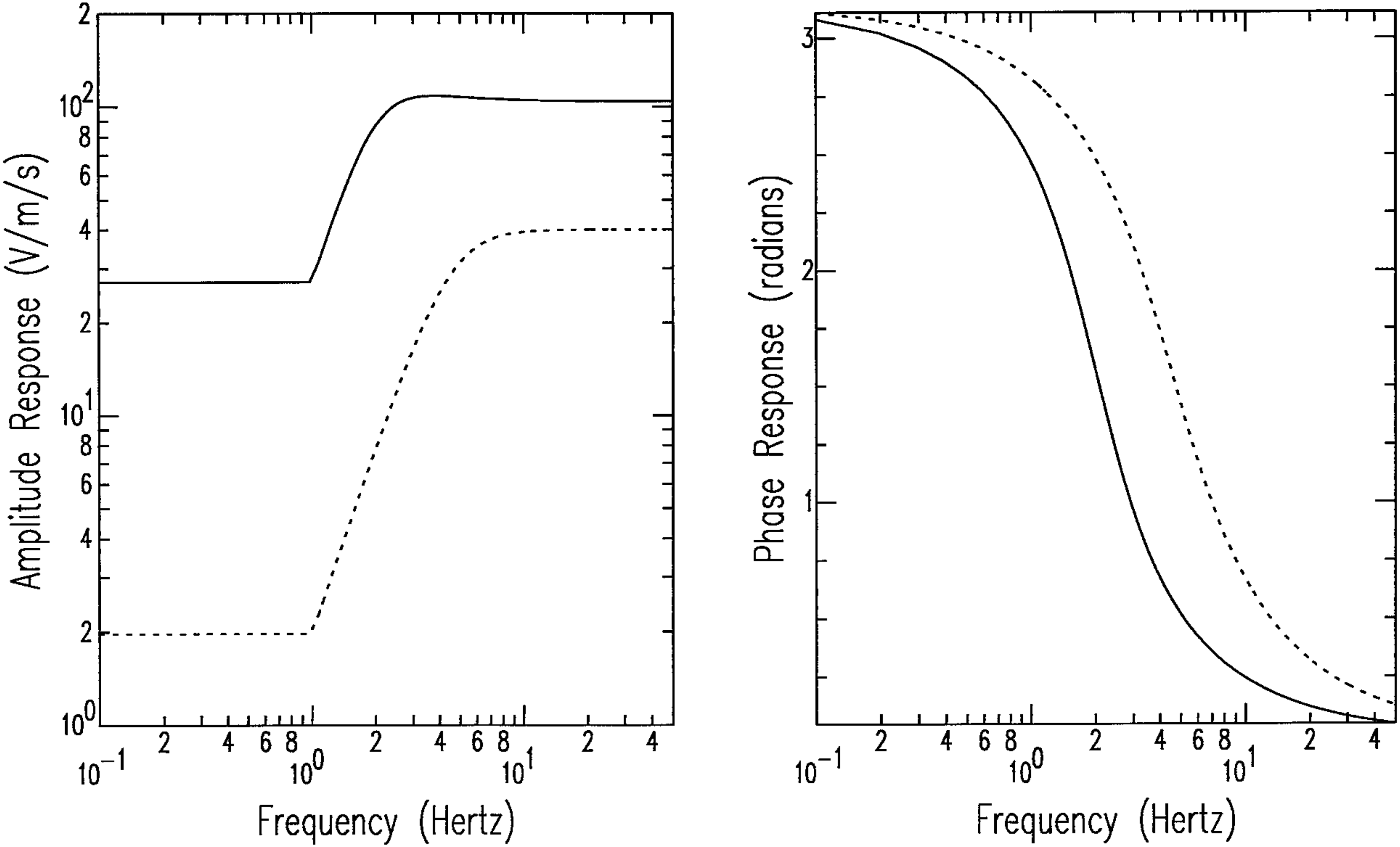
The two types of seismometers employed by DMG are Sprengnether S-6000 2 Hz triaxial surface packages and Mark Products L-10-3D-SWC 4.5 Hz triaxial downhole packages with sidewall bow-spring clamps. The recording system consisted of Sprengnether DR-100 digital event-recorders connected to a Sprengnether DR-101 group trigger module, which significantly reduced false triggering when the array was fully deployed. Dynamic range of the recording system is 66 dB and the sampling rate was chosen to be 100 samples per second (sps). The effective seismometer response for both seismometer types when attached to a DR-100 recorder and after allowing for amplifier gain is shown in figure 10. Calibration of clock drift on each DR-100 recorder was accomplished by periodically recording (once or twice a week) one second timing pulses from a Sprengnether TS-400 portable clock set to the WWV time standard. Inter-recorder timing accuracy is to within one sample interval (.01 sec.). A Sprengnether DP-100 playback unit with an RS232 interface module was used to play back field cassette tapes into a PR1ME 2250 computer for preliminary processing.

Siting

A huddle test was conducted at the Rock South site (figure 2) by placing the downhole seismometers side-by-side at the top of the California Strong Motion Instrumentation Program (CSMIP) downhole instrument hole and by placing the surface packages side-by-side next to that hole. Orientations of seismometer components where confirmed and two earthquakes were eventually recorded after recording system problems were diagnosed and repaired. Then the array was deployed at each of the four CSMIP instrumentation sites. figure 11 shows the placement of the strong-motion sensors in cross-section and identifies the seven surface and downhole sensor

Figure 10: Seismometer Response Curves

S6000 solid lines; L10 dashed lines



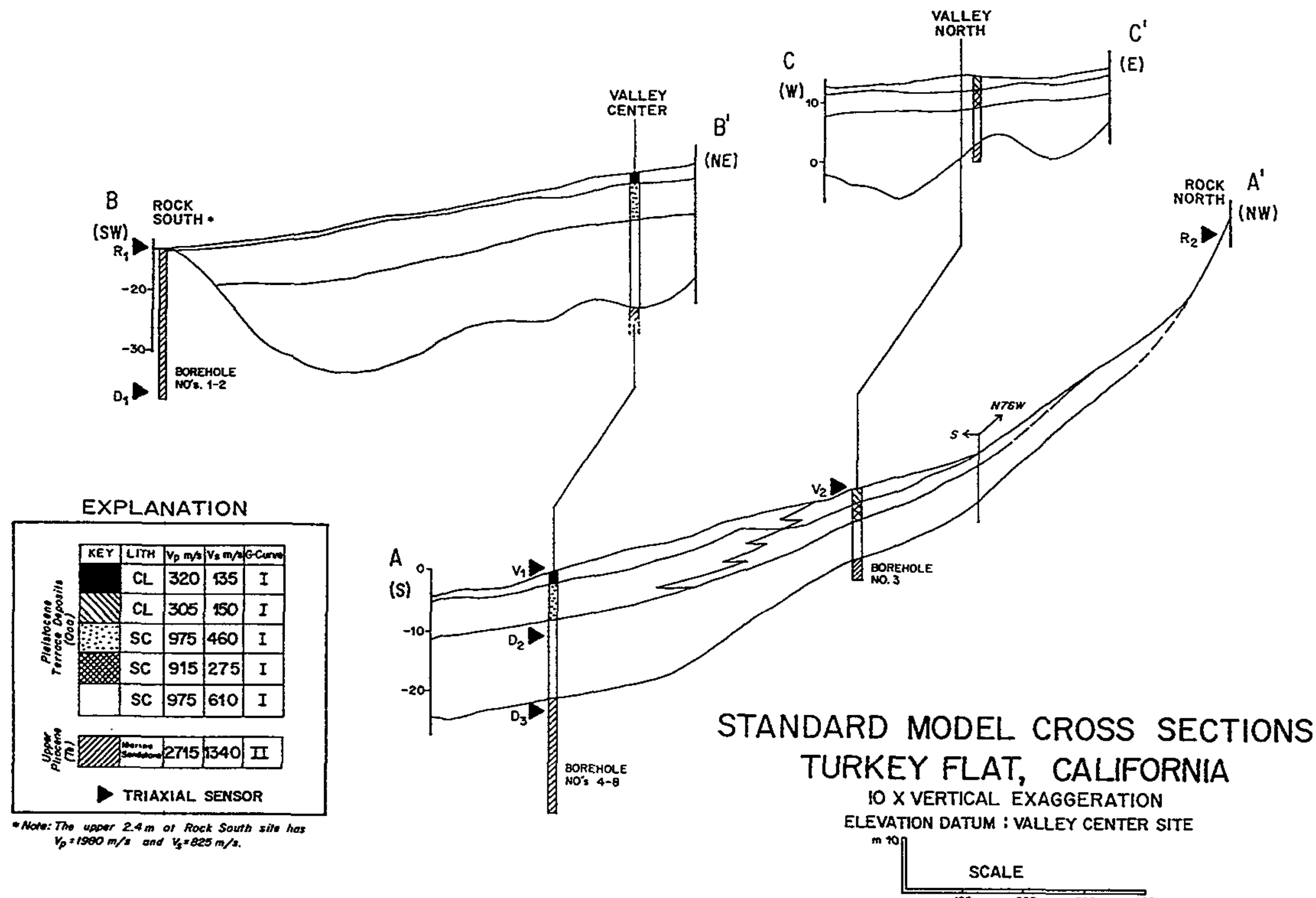

STANDARD MODEL CROSS SECTIONS
TURKEY FLAT, CALIFORNIA
10 X VERTICAL EXAGGERATION
ELEVATION DATUM : VALLEY CENTER SITE
SCALE
m 10
100
200
300
400m
B
(SW)
ROCK SOUTH *
R1
D1
-20
-30
BOREHOLE NO's. 1-2
VALLEY CENTER
B'
(NE)
C
(W)
10
0
VALLEY NORTH
C'
(E)
ROCK NORTH
A'
(NW)
R2
N76W
S
V2
BOREHOLE NO. 3
A
(S)
0
-10
-20
V1
D2
D3
BOREHOLE NO's 4-8
EXPLANATION
KEY
LITH
Vp m/s
Vs m/s
G-Curve
Pleistocene Terrace Deposits (Qoo)
CL 320 135 I
CL 305 150 I
SC 975 460 I
SC 915 275 I
SC 975 610 I
Upper Pliocene (Tl)
Marine Sandstone 2715 1340 II
TRIAXIAL SENSOR
* Note: The upper 2.4 m at Rock South site has Vp = 1980 m/s and Vs = 825 m/s.

Figure 11

locations of the Turkey Flat strong-motion array. The weak-motion sensors could not be collocated exactly next to the strong-motion sensors, so adjacent existing holes where used to place the weak-motion downhole seismometers at the same depth as the strong-motion downhole sensors and the surface weak-motion seismometers were placed in the ground next to the strong-motion surface sensor/recorder pads (figure 12). Table 3 lists the sensor location, recorder name, latitude, longitude, depth, and dates of operation of all seven weak-motion records available for this test.

Data Processing

Thirty-three local and regional earthquakes were recorded on the weak-motion array. One event with high signal to noise ratios in the 1-20 Hertz band has been selected as the test event for the low-strain level (weak-motion) prediction test. The remaining events serve as a control to show that the selected event does not have an unusual site response.

The original velocity records for the event selected for the low-strain level prediction test have been processed and prepared for distribution to participants as acceleration records. Computer processing was initially done on a PR1ME 2250 system and then completed on a SUN 3/280 system using Lawrence Livermore National Laboratory's Seismic Analysis Code (SAC) (Tull, 1987) and

Figure 12: Site Maps Showing Weak & Strong Motion Sensors And Test Holes

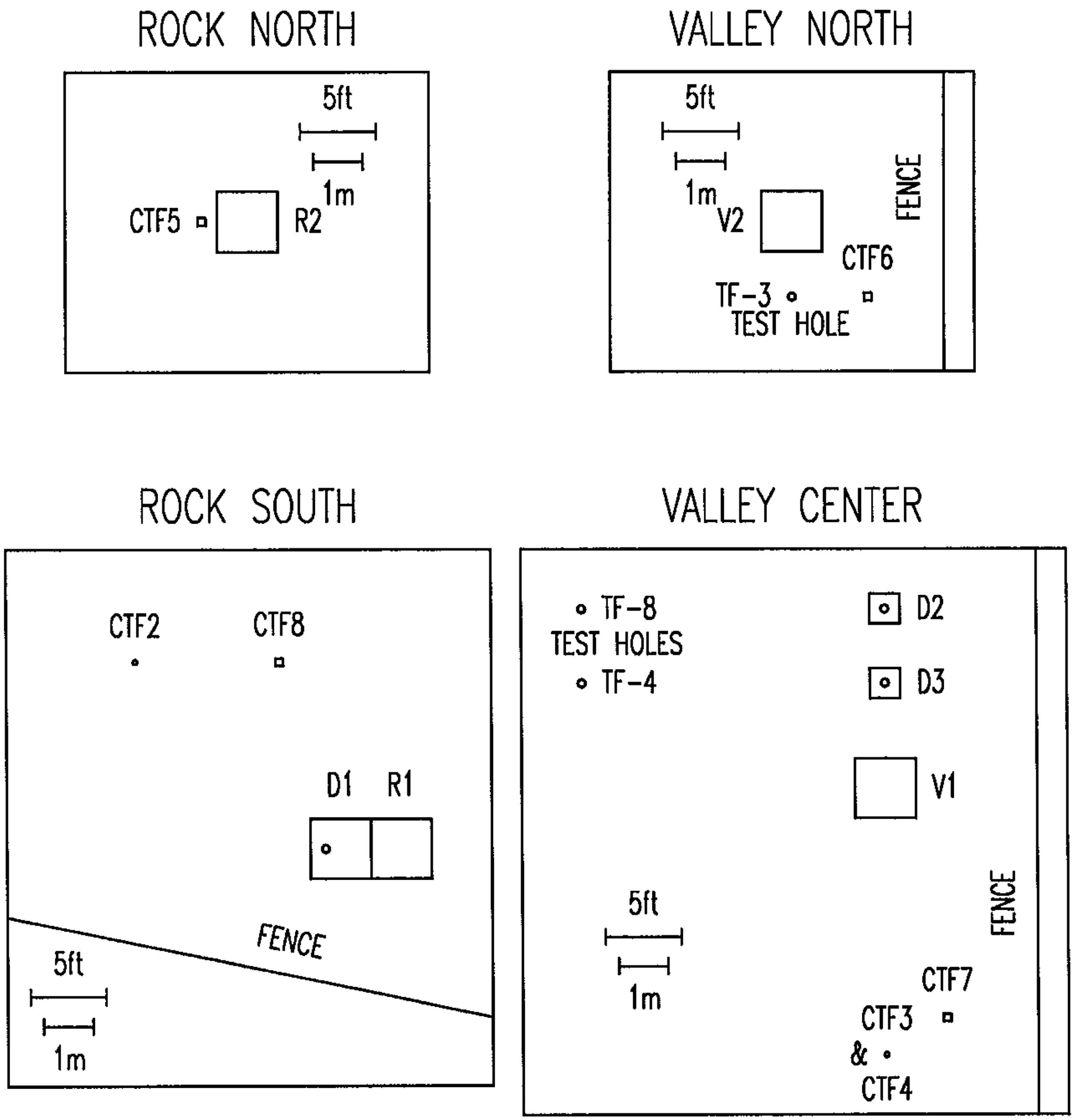


Table 3: Weak-motion Station Parameters

Site/ Recorder	Latitude Deg Min	Longitude Deg Min	Elev M	Dp* M	Operational Dates Start - End
R1 (CTF8)	35 52.6581	120 21.6648	494	0	25 Jan 88 - 02 Jun 88
R2 (CTF5)	35 53.4585	120 21.1447	561	0	25 Jan 88 - 02 Jun 88
V1 (CTF7)	35 52.9160	120 21.0030	506	0	25 Jan 88 - 02 Jun 88
V2 (CTF6)	35 53.1820	120 21.0030	515	0	25 Jan 88 - 02 Jun 88
D1 (CTF2)	35 52.6581	120 21.6648	494	24	25 Jan 88 - 02 Jun 88
D2 (CTF3)	35 52.9160	120 21.0030	506	10	25 Jan 88 - 02 Jun 88
D3 (CTF4)	35 52.9160	120 21.0030	506	23	25 Jan 88 - 02 Jun 88

* Depth below surface

Table 4: Clock and Orientation Corrections

Recorder	Clock Correction (sec)	P-pulse Orientation (degrees)	Orient. Correction (degrees)
CTF2	-.01 +/- .01	170 +/- 5	25 +/- 10
CTF3	-.02 +/- .01	135 +/- 5	60 +/- 10
CTF4	-.05 +/- .01	320 +/- 5	-125 +/- 10
CTF5	-.01 +/- .01	185 +/- 5	
CTF6	-.03 +/- .01	190 +/- 5	
CTF7	.01 +/- .01	195 +/- 5	
CTF8	.01 +/- .01	195 +/- 5	

Table 5: Instrument Parameters

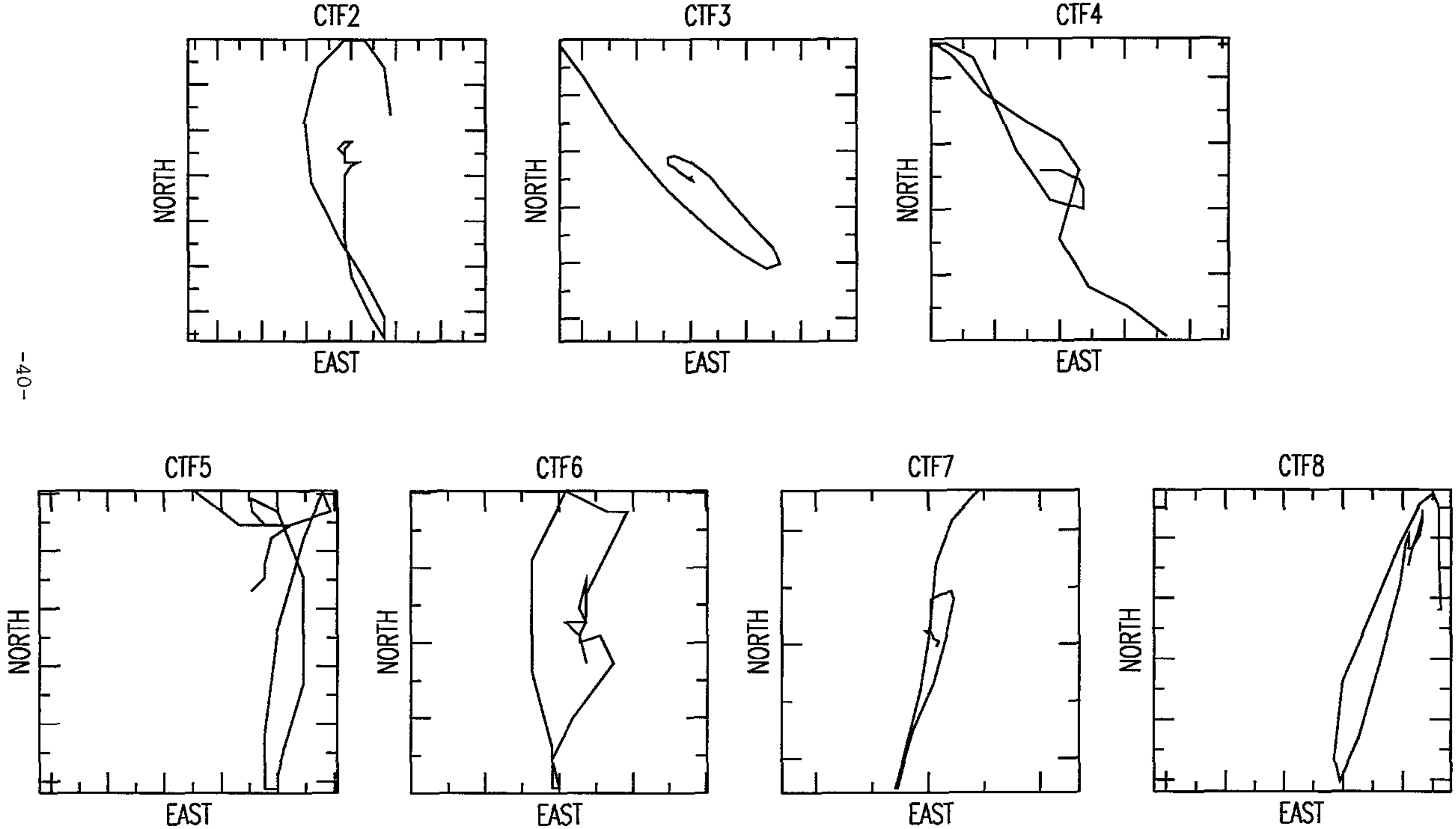
Seis Type	Effective GenCon (V-s/m)	Damping	Free Period (Hz)
S6000	104.	.6	2.0
L10	40.	.7	4.5

supplemental programs written by one of the authors (CHC). First clock and seismometer orientation corrections were determined and applied to the records. Next, the records were instrument corrected and transformed to acceleration time histories using frequency domain techniques. The resulting accelerograms have been bandpass filtered with a 2 pole Butterworth filter with corners at 1 and 20 Hertz. Huddle test records have been used to confirm that the instrument correction successfully removes the instrument response from the records.

Clock & Orientation Corrections

Table 4 lists the clock and orientation corrections applied to the weak-motion test records for each station of the array. The clock correction was determined by linearly interpolating the clock drift between a time calibration record before and a time calibration record after the recorded event. Seismometer orientations were determined from the particle-motion plots shown in figure 13. The particle motion used in the determination is the first cycle of the first strong P-wave arrival of the selected event. Note that the particle motion of the surface seismometers (CTF5-CTF8), which have a known north-east alignment to within five degrees, agree to within plus or minus five degrees. The orientation correction for the downhole seismometers is that needed to rotate their particle motion plots to match that of the surface

Figure 13: Initial P-wave Particle Motion



seismometer at the top of their hole. As indicated, it is believed that the orientations of the seismometers can be determined to within five degrees and hence the orientation correction for the downhole seismometers is known to within ten degrees. Using SAC, the clock and orientation corrections listed were added to the start time and component orientation of each trace for a station and then the downhole horizontal traces were rotated into true north and east components.

Instrument Correction

The appropriate instrument response depicted in figure 10 has been removed from each trace of the weak-motion test event. Notice that below 1 Hertz the instrument amplitude response has been held equal to the amplitude response at 1 Hertz so that long-period noise is not overamplified when the instrument correction is made. Table 5 lists the instrument free period, damping, and effective generator constant used in making these corrections. Free period and damping have been taken from the instrument manufacturers specifications, and the effective generator constant determined from seismometer/recorder resistances, seismometer step-calibration response, and huddle-test amplitude responses (see Correction Check below). The instrument response was removed from a trace by Fast Fourier Transforming (FFT'ing) the record to the frequency domain, dividing out the instrument amplitude response from the record amplitude response, subtracting the instrument phase response from the record phase response, and finally Inverse Fast Fourier Transforming (IFFT'ing) back to the time domain. This is the same as deconvolving the instrument response from the record (Bracewell, 1965, p 110). Specifically, the velocity response removed is

$$|I| = \frac{f^2}{\left((f^2 - fo^2)^2 + (2 \beta\, fo\, f)^2 \right)^{1/2}}$$

and

$$\Phi i = -\tan^{-1} \frac{2 \beta\, fo\, f}{fo^2 - f^2} + \pi \,,$$

where $|I|$ is the instrument amplitude response, Φi is the instrument phase response, f is frequency (Hertz), fo is free period (Hertz), and β is damping (Aki and Richards, 1980, p 479-80 with phase response corrected per Saucedo and Schiring, 1968, p 400-1). The addition of π to the phase maintains the previously known ground motion polarity of the record.

Transformation to Acceleration

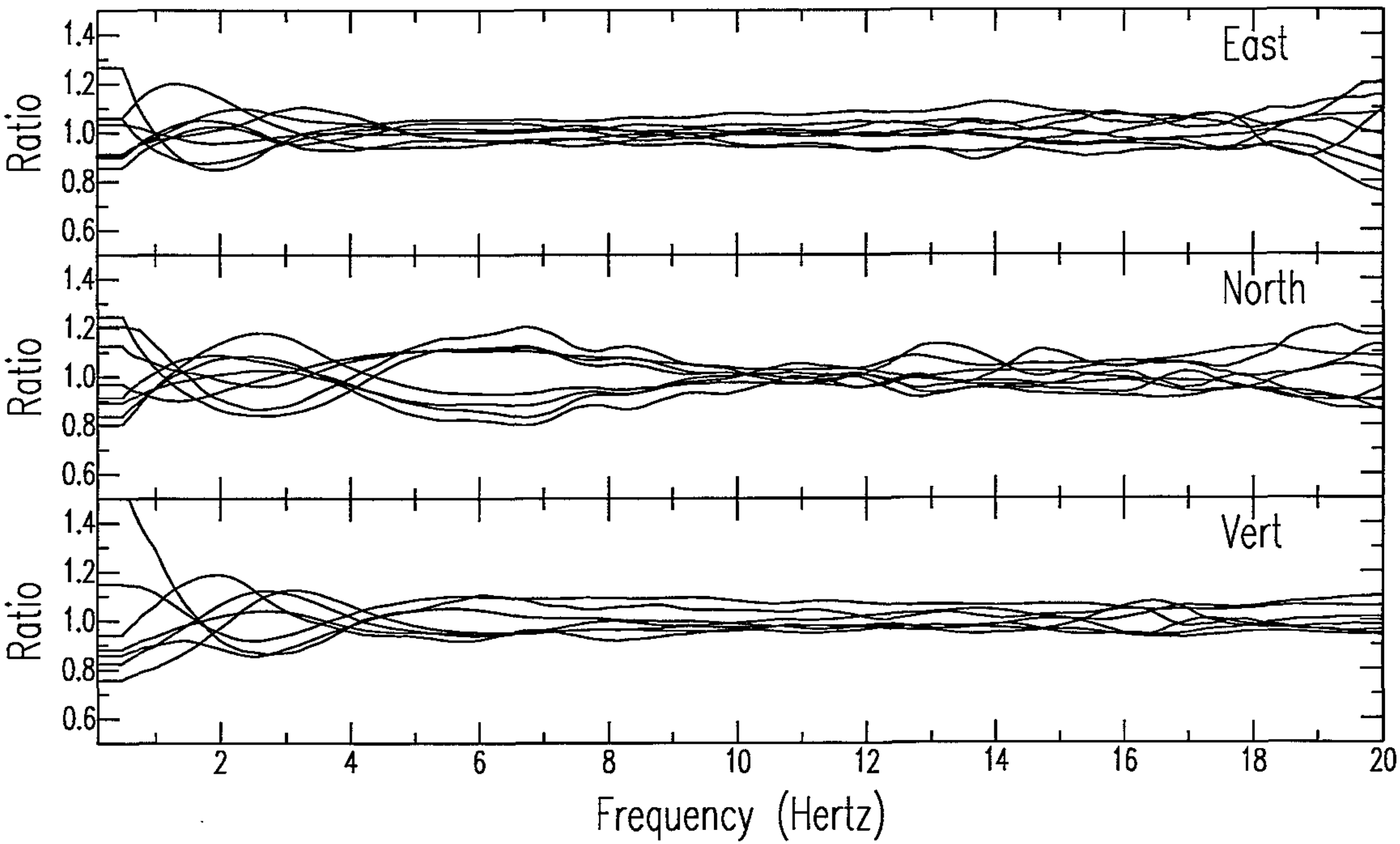
For the purpose of matching the expected records from the Turkey Flat strong motion array that will be used in the high strain level prediction test, the low strain level test records have been transformed from the velocity domain to the acceleration domain.

Prior to IFFT'ing the instrument-corrected velocity amplitude and phase spectra back to the time domain, the velocity spectra have been rotated into acceleration spectra by multiplying the amplitude spectra by 2pf and subtracting p/2 from the phase spectra. After the IFFT, the time histories become acceleration time histories. In order to remove noise amplified by the above processing, acceleration time histories have been bandpass filtered using SAC's 2 pole Butterworth filter with corner frequencies at 1 and 20 Hertz.

Correction Check

As a check on the validity of the instrument correction performed on the weak-motion test data, the huddle test event with high signal to noise ratios between 1 and 20 Hertz has been processed in the same manner as the test event and acceleration amplitude spectra and time histories compared between the two instrument types. Figure 14 shows the residual noise in spectral amplitude of the bandpass-filtered huddle-test acceleration records by component. For each component, smoothed whole-seismogram spectral ratios for each station with respect to the average spectrum of that component are plotted in figure 14. Smoothing is accomplished by a 41-point running mean filter applied twice which roughly corresponds to smoothing over a 0.5 Hertz window. Note that the residual spectral amplitude varies between 10% and 20% over the 1 to

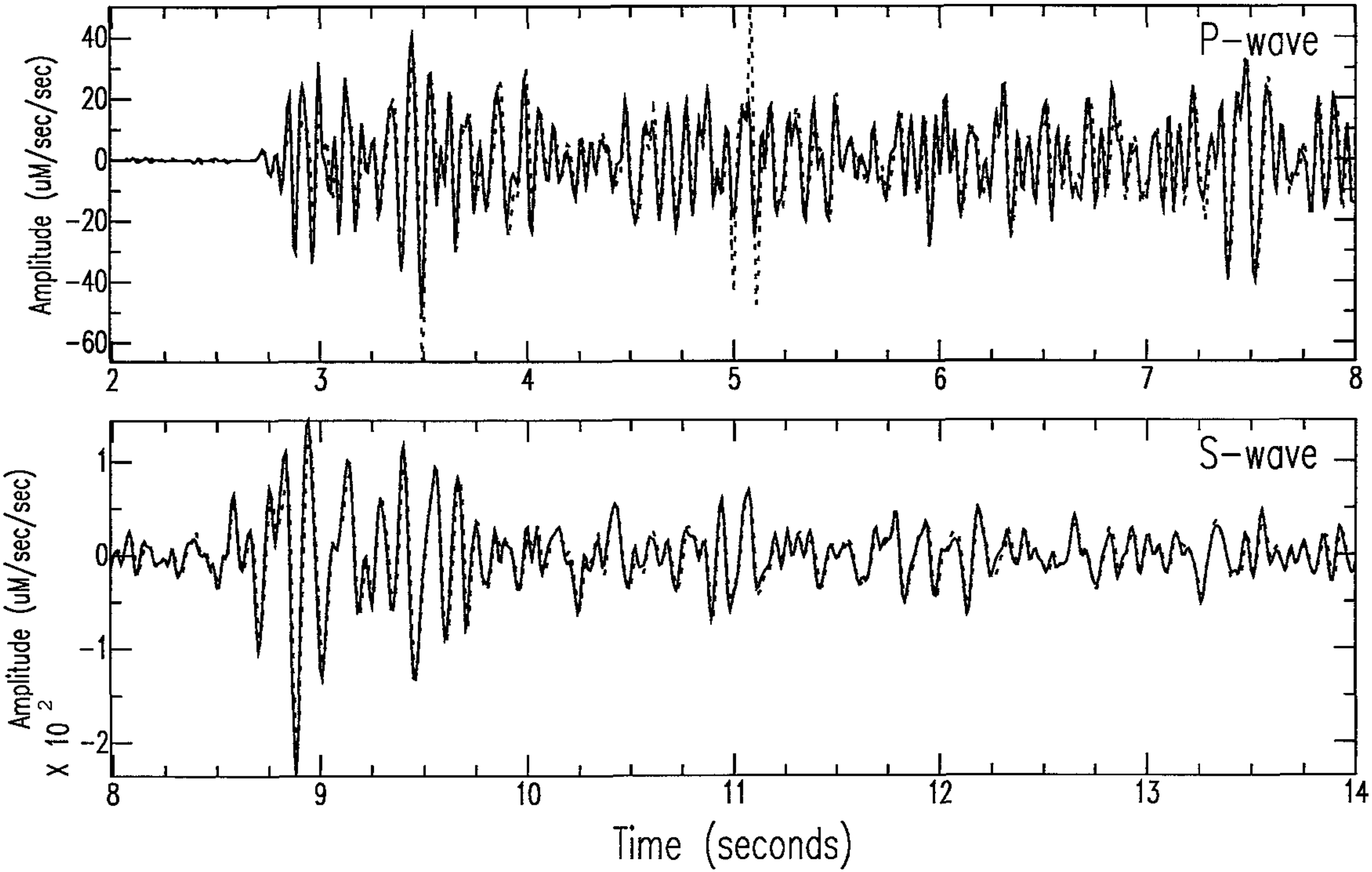
Figure 14: Huddle Test Residual Amplitude Noise by Component



20 Hertz band which compares favorably with Jarpe, et al.'s (1988) 8% residual noise for a similar comparison for one seismometer type. In figure 15, huddle-test east-component accelerograms from one downhole and one surface seismometer are directly compared by overlaying the traces. Although the amplitude varies somewhat (within 15-20%), the phase relationship between the traces matches very well over both the P-wave and S-wave windows, suggesting a good phase correction for instrument type.

Figure 15: Huddle Test S6000 vs L10 Accelerogram Comparison

S6000 solid lines; L10 dashed lines



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Jarpe, S.P., Cramer, C.H., Tucker, B.E., and Shakal, A.F., 1988, A comparison of observations of ground response to weak and strong ground motion at Coalinga, California: Bull. Seism. Society of Am. v. 78, n. 2, p. 421-435.

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VOLUME 2 FILE FORMAT

A Volume 2 file contains the instrument and base-line corrected data corresponding to the data in a Vol. 1 file. For each of the channels, the file has three headers, followed by the acceleration time series, the velocity time series, and the displacement time series. Specifically, the elements of a Vol. 2 file, for each channel, are:

1. Text header, alphanumeric
2. Integer header
3. Real-value header
4. Acceleration data-start line
5. Acceleration data, equal time spacing
6. Velocity data-start line
7. Velocity data, equi-spaced
8. Displacment data-start line
9. Displacement data, equi-spaced.
10. End-of-data flag

These 10 elements are then repeated for the next channel. Similar to the Vol. 1 headers, the text header contains the most information and is best for scanning by an investigator. Portions of the Vol. 2 headers are the same as the corresponding Vol. 1 headers; thus, complete information about the Vol. 1 processing, etc. can be obtained from the Vol. 2 header without having to read the Vol. 1 file.

Each of the headers is described on the following pages. These descriptions are followed by a sample Fortran program for reading a Volume 2 file, and by an actual listing of a complete header.

VOLUME 2 TEXT HEADER (TXTHDR)

The text header occupies 25 lines of alphanumeric data, which are the first 25 lines of the information for a given channel. The contents of each line are given in the following. (Lines 2 through 11 are identical to lines 1 through 10, respectively, of the Volume 1 text header.)

Line	Column	Description
1	1-80	Vol. 2 title line, which includes record identifier and channel identification
2	1-80	Vol. 1 title line, which includes processing date and directory identifier
3	1-40	Earthquake name (actual number of characters used in name is element 29 of integer header array, IHDR)
4	1-40	Earthquake date, time (local time)
	41-80	Earthquake origin time (GMT)
5	1-24	Accelerogram identification number
	36-77	Trigger time (GMT), if available
6	13-17	Station number
	21-27	Station latitude; N or S in column 27
	30-37	Station longitude; E or W in column 37
	40-47	Instrument type (e.g., SMA, RFT, CRA)
	54-57	Instrument serial number
	If other	than a single triaxial instrument at this station, then:
	60-61	Number of channels on this accelerograph
	71-72	Total number of channels at station (if different)
7	1-40	Station name (actual number of characters used in name is element 30 of integer header IHDR).
8	6-7	Accelerogram channel number of this component
	10-14	If horizontal component, azimuth (0-360, measured clockwise from North, in cols 10-12); if vertical component, 'UP ' or 'DOWN'. (* Also see note for IHDR(27).)
	29-30	Station channel number, if multi-instrument station
	47-80	Description of sensor location in structure, when appropriate
9	1-80	Earthquake title line, including name and date (actual no. of characters used in title line is element 31 of IHDR)
10	1-45	Earthquake hypocenter information (latitude, longitude, depth)
	46-80	Earthquake magnitude (ML; other magnitudes may also be listed)
11	15-21	Transducer natural period (seconds)
	39-43	Damping (fraction of critical)
	60-64	Sensitivity (Cols 66-72: Units, typically cm/g)
12	40-46	Length in seconds of Vol. 2 digitized record

13	51-55	Vol. 1 peak acceleration (g)
	64-70	Time of peak acceleration (seconds after triggering)
14	31-36	RMS of Vol. 1 acceleration (g)
15	1-80	Frequency limits used in the band-pass filtering
16	1-6	Number of Vol. 2 acceleration, velocity and displacement points
17	1-45	Time step of Vol. 2 data (equally-spaced)
18	1-64	Value and time of Vol. 2 peak acceleration (time, in seconds after triggering)
19	1-64	Value and time of peak velocity
20	1-64	Value and time of peak displacement
21	1-78	Initial velocity and displacement (computed during processing)
22	1-80	Earthquake name (same as line 9, or line 8 of Vol. 1 header)
23	-	Blank
24	1-80	Titling line, used for plot titling
25	-	Blank, or additional plot titling if needed.

VOLUME 2 INTEGER HEADER (IHDR)

The integer-value header is a 100-element integer array, written in lines 26-32 of the header information for a given channel (in format 16I5). Only the first two-thirds of the array elements are now used, as described in the following. (Elements 1-50 are identical to those of the Volume 1 integer header.)

Line	Array Element	Description
26	1	Accelerogram channel number
	2	1, not used
	3	Station channel number (same as element 1 if there is only one instrument at the station)
	4	Number of channels on accelerogram
	5	Total number of channels at station
	6	0, not used
	7	Shock number (1 unless more than one earthquake per trigger)
	8	1, indicating that a direct-copy negative was digitized medium
	9-16	0, not used
27	17-26	0, not used
	27	Orientation of sensor for this channel. For horizontal sensor, value is azimuth, measured clockwise from North, 0-360 degrees. For vertical sensor, 500=Up, 600=Down. (* See note below)
	28	Number of digitized acceleration data points
	29	Number of letters in earthquake name (line 3 of TXTHDR)
	30	Number of letters in station name (line 7 of TXTHDR)
	31	Number of letters in earthquake title line (line 9 of TXTHDR)
	32	Azimuth of Reference North of the structure, clockwise from true North; 0, for a free-field accelerogram **
28	33-48	0, not used
29	49-50	0, not used
	51,52	Number of digitized acceleration data points, same as IHDR(28)
	53	Number of Vol. 2 acceleration data points
	54	First decimation factor in processing (typically 4)
	55	Decimation factor for long-period filtering of accelerations (typically 10)
	56	Half-length of filter operator in BAS
	57	0, not used
	58	0, not used
	59	Number of letters in earthquake title, same as IHDR(31), for plotting
	60	Number of letters for plotting station name
	61	Decimation factor for long-period filtering of velocity (typically 10)
	62	Decimation factor for long-period filtering of displacement (typically 10)
	63	0, not used
	64	Number of velocity points

6.

30	65	0, not used
	66	Number of displacement points
	67-80	0, not used
31	81-96	0, not used
32	97-100	0, not used

Notes: * For a structure, sensor azimuth is given relative to Reference North for the structure. In all cases, the orientation given corresponds to positive (+y) motion on the record.

** For example, if a structure's Reference North is aligned 18 degrees clockwise from (true) North, and a sensor is aligned East with respect to the structure's reference, then IHDR(32)=18 and IHDR(27)=90 (though the sensor is oriented at 108 degrees from true North).

VOLUME 2 REAL-VALUE HEADER (RHDR)

The real-value header is a 100-element floating-point array, written in lines 33-45 of the header (in format 8F10.3). Only the first 76 elements of the array are now used, as described in the following. (Elements 1-50 are the same as the corresponding elements in the Vol. 1 header. Elements 10-16 are defined specifically for digitization by CSMIP.)

Line	Array Element	Description
33	1	Natural period of transducer (seconds)
	2	Damping of transducer (fraction of critical)
	3	Length of digitized record (in seconds)
	4	RMS value of digitized record (in g)
	5	Units of digitized acceleration in file (fractions of g, typically 0.10)
	6	Sensitivity of transducer (cm/g)
	7	Peak acceleration (Vol.1) for this component (in g)
	8	Time of peak acceleration value (seconds after trigger)
34	9	Natural frequency of transducer (in Hz)
	10	Digitizer y-step (acceleration) size, in microns (cm/10000)
	11	Digitizer y-step size, in milli-g
	12	Digitizer x-step (time) size, in microns (cm/10000)
	13	Actual average time step of digitized record, in milliseconds
	14	Standard deviation of time step, in milliseconds
	15	Minimum time step size, as digitized (milliseconds)
	16	Maximum time step size, as digitized (milliseconds)
35	17-24	0.0, not used
36	25-32	0.0, not used
37	33-40	0.0, not used
38	41-48	0.0, not used
39	49-51	0.0, not used
	52	Scaling factor for converting acceleration from g/10 to cm/sec/sec (98.0665)
	53	Time step of Vol. 2 equally-spaced interpolation (sec)
	54	Length of interpolated Vol. 2 acceleration (secs)
	55	Natural frequency of transducer (radians/sec)
	56	0.0, not used
40	57	0.0, not used
	58	Terminal frequency of high-frequency filter (Hz)
	59	Roll-off width of high-frequency filter (Hz)
	60	Length of Vol. 2 output after resampling to sampling interval given in RHDR(53)
	61	Time step of Vol. 2 output (sec)
	62	Roll-off corner frequency of long-period filter (Hz)
	63	Roll-off width of long-period filter (Hz)
	64	0.0, not used

41	65	Time of peak acceleration (Vol. 2), seconds
	66	Peak acceleration value (Vol. 2), cm/sec/sec
	67	Time of peak velocity (sec)
	68	Peak velocity (cm/sec)
	69	Time of peak displacement (sec)
	70	Peak displacement (cm)
	71	Initial velocity value (cm/sec)
	72	Same as RHDR(62)
42	73	Roll-off corner frequency of high-frequency filter (Hz)
	74	Velocity time step (sec)
	75	Displacement time step (sec)
	76	Initial displacement (cm)
	77-80	0.0, not used
43-45	81-100	0.0, not used

EXAMPLE FORTRAN CODE FOR READING A VOLUME 2 FILE

A file can be read as follows (an example using Fortran IV):

```
      INTEGER IHDR(100), TXTHDR(40,25), ENDCHN
      REAL RHDR(100), A(3000), V(3000), D(3000)
C
C  --- READ HEADERS ---
      READ(LUVOL2,100) ((TXTHDR(IWRD,LINE), IWRD=1,40), LINE=1,25)
      READ(LUVOL2,200) (IHDR(I), I=1,100)
      READ(LUVOL2,300) (RHDR(I), I=1,100)
  100 FORMAT(40A2)
  200 FORMAT(16I5)
  300 FORMAT(8F10.3)
  400 FORMAT(I5)
C
C  --- READ THE ACCELERATION, VELOCITY AND DISPLACEMENT ---
      READ(LUVOL2,400) NPTSA
      READ(LUVOL2,300) (A(I), I=1,NPTSA)
C
      READ(LUVOL2,400) NPTSV
      READ(LUVOL2,300) (V(I), I=1,NPTSV)
C
      READ(LUVOL2,400) NPTSD
      READ(LUVOL2,300) (D(I), I=1,NPTSD)
C
C  --- READ THE END-OF-DATA FLAG FOR THIS CHANNEL, WHICH SHOULD BE HERE ---
      READ(LUVOL2,100) ENDCHN
      IF(ENDCHN .NE. '/&') STOP 1
```

===

Notes:

```
               LUVOL2 = FORTRAN logical unit number for the Vol. 2 file, assumed
                          to be previously opened
        TXTHDR(40,25) = 25 lines of text headers, 40 2-character words per line

            IHDR(100) = 7 lines of integer headers

            RHDR(100) = 13 lines of real-value headers

  NPTSA,NPTSV,NPTSD = number of acceleration, velocity, displacement data points
                          (these values could also be obtained from IHDR array:
                          NPTSA=IHDR(53), NPTSV=IHDR(64), and NPTSD=IHDR(66))
  A(3000),V(3000),D(3000) = arrays for Vol. 2 acceleration, velocity, and
                          displacement.  Dimensions of these arrays have to be
                          sufficient for the actual number of data points.
               ENDCHN = End-of-data mark for this channel (a "/&" flag is used)
```

Sample Volume 2 File Listing for Turkey Flat experiment:

```
CORRECTED ACCELEROGRAM  R1 (CTF8)                       CHAN  1:  90 DEG    FROM  N
UNCORRECTED VELOCITY DATA                       PROCESSED: 05/18/88, CDMG EVENT12
TURKEY FLAT, USA, WEAK-MOTION TEST EVENT              STANDARD    GEOTECHNICAL MODEL
APRIL 26, 1988 18:29 PST                      (ORIGIN(USGS):  4/27/88,  2:29:25.29GMT)
WEAK-MOTION EVENT 12                     TRIGGER TIME:  4/27/88,  2:29:30.80GMT
STATION NO. CTF8    35.878N, 120.361W     DR100  S/N  151 ( 3 CHNS OF  3 AT STA)
TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)       PREDICTION BY JOAN S. DOE
CHAN  1:  90 DEG  (STA CHN:  3)
COALINGA AREA EARTHQUAKE
HYPOCENTER(USGS): 36.183N,120.329W, H= 4KM.  ML=2.0(USGS).
INSTR PERIOD = 0.50   SEC,  DAMPING =  0.6 ,  SENSITIVITY = 104. V/M/S
                        RECORD LENGTH =  28.72 SEC.
                                     UNCOR MAX  =        G, AT         SEC.
RMS ACCEL OF (UNCOR) RECORD  =       G.
TWO POLE BUTTERWORTH BANDPASS FILTERED WITH CORNERS AT  1 AND 20 HZ.
  2873 POINTS OF INSTRUMENT- AND BASELINE-CORRECTED ACCEL                    DATA
AT EQUALLY-SPACED INTERVALS OF   0.010  SEC.
PEAK ACCELERATION =  -415.426    uM/SEC/SEC  AT      7.840  SEC.  (uM=10**-6M)
PEAK   VELOCITY   =     9.047      uM/SEC     AT      7.870  SEC.
PEAK DISPLACEMENT =    -0.3527      uM       AT    10.770  SEC.
INITIAL VELOCITY  =     0.0074  uM/SEC;   INITIAL DISPLACEMENT =   -0.00173 uM
COALINGA AREA EARTHQUAKE

WEAK-MOTION EVENT 12, TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)   CHAN  1:  90 DEG

     1    1    1    3    3    0    1    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0   90 2873   40   40   25    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0 2873 2873 2873    0    0    0    0    0   25   80    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0
      0.500      0.600     28.720      0.000      0.000      0.000      0.000      0.000
      2.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000     12.566      0.000
      0.000      0.000      0.000      0.000      0.010      0.000      0.000      0.000
      7.840   -415.426      7.870      9.047     10.770     -0.353      0.007      0.000
      0.000      0.000     -0.002      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000
 2873 POINTS OF ACCEL DATA EQUALLY SPACED AT 0.010 SEC.  (UNITS: uM/SEC/SEC)
     -0.290      0.754      0.601      0.106     -0.012      0.031      0.084      0.101
      0.079      0.116     -0.049     -0.691     -0.290      0.753      0.582      0.130
     -0.158     -0.749     -0.398     -0.185     -0.531      0.230      0.391      0.027
     -0.140      0.045      0.665      0.486     -0.117     -0.854     -0.361      0.563
         ...
         ... (Remainder of acceleration data) ...
         ...
/&    <----- (End of data for this channel)
         ...
         ... (Header, etc for next channel)
         ...
         ...
```

RESPONSE SPECTRA FILE FORMAT

A Response Spectra (RS) file contains RS information for a specific station. For each channel included in the file, the file has three headers, spectral parameters, and values of one response spectra at each of up to 100 periods. Specifically, the elements of an RS file, for each channel, are:

1. Text header, alphanumeric
2. Integer header
3. Real-value header
4. Damping value for the response spectrum
5. Periods at which the spectrum is computed
6. Pseudovelocity response spectrum values
7. End-of-data flag (/&)

These seven elements are then repeated for the next channel in the file. The text header is very similar to the Volume 2 text header. The integer header is the same as that of the Volume 2 file except for three elements. The real-value header is identical to that of the Volume 2 file.

The headers and file contents are described on the following pages. These descriptions are followed by an actual listing, in summary form, of a RS file.

RS TEXT HEADER (TXTHDR)

The text header occupies 3Ø lines of alphanumeric text, which are lines 1-3Ø of the information for a given channel. This text header is nearly identical to the text header for the corresponding Volume 2 file.

Line	Column	Description
1	1-8Ø	RS title line
2-16	-	Same as lines 1-15 of Volume 2 text header, except line 4, col. 51-8Ø indicates geotechnical model used and line 7, col. 45-8Ø indicates whether data is observed, or predicted and by whom.
17	18-51	Same as line 16 of Volume 2 text header with only characters in col. 18-51 copied over.
18-22	-	Blank
23-26	-	Same as lines 22-25 of Volume 2 text header
27-28	-	Same as lines 25 and 26
29-3Ø	-	Units of spectra

RS INTEGER HEADER (IHDR)

The integer-value header is a 1ØØ-element array, written in lines 31-37 of the header, in format 16I5. It is identical to the integer array for the Volume 2 file, except for elements 67-69.

Line	Array Element	Description
31-37	1-1ØØ	Same as elements 1-1ØØ of Volume 2 integer header, except element 67 which is no. of letters for plotting station name (IHDR(6Ø)+1), element 68 which is no. of periods for which spectral values are computed, and element 69 which is no. of damping values for which response spectral values are computed (always 1)

RS REAL-VALUE HEADER (RHDR)

The real-value header is a 1ØØ-element floating-point array, written in lines 38-5Ø of the header, in format 8F1Ø.3. The header is identical to the corresponding header for a Volume 2 file.

Line	Array Element	Description
38-5Ø	1-1ØØ	Same as elements 1-1ØØ of Volume 2 real-value header; Peak acceleration, velocity, and displacement are required in elements 66, 68, & 7Ø respectively, even if a Volume 2 file is not provided.

RESPONSE SPECTRAL PARAMETERS

Line	Parameter	Description
51	DMPNG	Damping value used in response spectum
52-64	PD(I), I=1,1ØØ	Periods at which the spectrum is computed (standard values are: .Ø4, .Ø42, .Ø44, .Ø46, .Ø48, .Ø5, .Ø55, .Ø6, .Ø65, .Ø7, .Ø75, .Ø8, .Ø85, .Ø9, .Ø95, .1Ø, .11, .12, .13, .14, .15, .16, .17, .18, .19, .2Ø, .22, .24, .26, .28, .3Ø, .32, .34, .36, .38, .4Ø, .42, .44, .46, .48, .5Ø, .55, .6Ø, .65, .7Ø, .75, .8Ø, .85, .9Ø, .95, 1.Ø, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.Ø, 2.2, 2.4, 2.6, 2.8, 3.Ø, 3.2, 3.4, 3.6, 3.8, 4.Ø, 4.2, 4.4, 4.6, 4.8, 5.Ø, 5.5, 6.Ø, 6.5, 7.Ø, 7.5, 8.Ø, 8.5, 9.Ø, 9.5, 1Ø., 11., 12., 13., 14., and 15. seconds. These are 91 periods; the remaining 9 array elements are set to Ø.Ø)
65	- -	Label and damping for response spectral values
66-78	PV(I), I=1,1ØØ	Pseudovelocity response spectral values at periods PD(I).

Sample Response Spectra File Listing for Turkey Flat experiment:

```
RESPONSE AND FOURIER AMPLITUDE SPECTRA (51 PERIODS,  .04 -  1.0 SEC)   FOR
CORRECTED ACCELEROGRAM  R1 (CTF8)                  CHAN  1:  90 DEG     FROM  N
UNCORRECTED VELOCITY DATA                    PROCESSED: 05/18/88, CDMG EVENT12
TURKEY FLAT, USA, WEAK-MOTION TEST EVENT            STANDARD   GEOTECHNICAL MODEL
APRIL 26, 1988 18:29 PST                    (ORIGIN(USGS):  4/27/88,  2:29:25.29GMT)
WEAK-MOTION EVENT 12                 TRIGGER TIME:  4/27/88,  2:29:30.80GMT
STATION NO. CTF8    35.878N, 120.361W    DR100  S/N  151 ( 3 CHNS OF  3 AT STA)
TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)     PREDICTION BY JOAN S. DOE
CHAN  1:  90 DEG  (STA CHN:  3)
COALINGA AREA EARTHQUAKE
HYPOCENTER(USGS): 36.183N,120.329W, H= 4KM.  ML=2.0(USGS).
INSTR PERIOD = 0.50   SEC,  DAMPING =  0.6 ,  SENSITIVITY = 104. V/M/S
                        RECORD LENGTH =  28.72 SEC.
                                     UNCOR MAX  =        G, AT          SEC.
RMS ACCEL OF (UNCOR) RECORD  =       G.
TWO POLE BUTTERWORTH BANDPASS FILTERED WITH CORNERS AT  1 AND 20 HZ.
                 INSTRUMENT- AND BASELINE-CORRECTED




COALINGA AREA EARTHQUAKE

WEAK-MOTION EVENT 12, TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)   CHAN  1:  90 DEG

WEAK-MOTION EVENT 12, TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)   CHAN  1:  90 DEG

UNITS FOR PSEUDOVELOCITY SPECTRUM IS uM/SEC.

    1    1    1    3    3    0    1    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0   90 2873   40   40   25    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0 2873 2873 2873    0    0    0    0    0   25   80    0    0    0    0
    0    0   81   51    5    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0
     0.500     0.600    28.720     0.000     0.000     0.000     0.000     0.000
     2.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000    12.566     0.000
     0.000     0.000     0.000     0.000     0.010     0.000     0.000     0.000
     7.840  -415.426     7.870     9.047    10.770    -0.353     0.007     0.000
     0.000     0.000    -0.002     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000
     0.050
     0.040     0.042     0.044     0.046     0.048     0.050     0.055     0.060
     0.065     0.070     0.075     0.080     0.085     0.090     0.095     0.100
        ... (Remainder of 100 element period array) ...
DAMPING =  .05. DATA OF PSSV  :
 0.300e+01 0.323e+01 0.338e+01 0.353e+01 0.373e+01 0.406e+01 0.493e+01 0.574e+01
        ... (Remainder of 100 element pseudovelocity array) ...
/&    <----- (End of data for this channel)
        ...
        ... (Header, etc for next channel)
        ...
```

FSR FILE FORMAT

A Fourier Spectral Ratio (FSR) file contains FSR information for a specific station with respect to a specified reference station. For each channel included in the file, the file has three headers and Fourier spectral ratio parameters either equally or unequally spaced in the frequency domain. Specifically, the elements of an FSR file, for each channel, are:

1. Text header, alphanumeric
2. Integer header
3. Real-value header
4. Frequency data-start line (unevenly-spaced only)
5. Frequency sample points (unevenly-spaced only)
6. Fourier spectral ratio data-start line
7. Fourier spectral ratio values
8. End-of-data flag (/&)

These eight elements are then repeated for the next channel in the file. The text header is very similar to the Volume 2 text header. The integer header is the same as that of the Volume 2 file except for one element indicating an evenly or unevenly spaced file. The real-value header is identical to that of the Volume 2 file.

The headers and file contents are described on the following pages. These descriptions are followed by an actual listing, in summary form, of a FSR file.

FSR TEXT HEADER (TXTHDR)

The text header occupies 25 lines of alphanumeric text, which are lines 1-25 of the information for a given channel. This text header is nearly identical to the text header for the corresponding Volume 2 file.

Line	Column	Description
1	1-8Ø	FSR title line giving reference station in col. 51-75
2-16	-	Same as lines 1-15 of Volume 2 text header, except line 4, col. 51-8Ø indicates geotechnical model used and line 7, col. 45-8Ø indicates whether data is observed, or predicted and by whom.
17	1-8Ø	FFT window line with start and end times from front of trace given in col. 38-44 & 64-7Ø.
18-9	1-8Ø	Smoothing lines with # times smoothed in line 18, col. 53 and filter width in line 19, col. 8-15. For evenly spaced file, filter width is in # points, and for unevenly spaced file, filter width is in Hz (see examples).
2Ø	1-8Ø	FSR data window line with start and end frequencies of FSR data given in col. 31-36 & 53-59.
21	1-8Ø	FSR sampling line with # of points in col. 1-5 and, for evenly sampled data only, interval size in col. 68-75 (Hz).
22-5	1-8Ø	Same as lines 22-25 of Volume 2 text header

FSR INTEGER HEADER (IHDR)

The integer-value header is a 1ØØ-element array, written in lines 26-32 of the header, in format 16I5. It is identical to the integer array for the Volume 2 file, except for element 4Ø.

Line	Array Element	Description
26-32	1-1ØØ	Same as elements 1-1ØØ of Volume 2 integer header, except element 4Ø which is 1 for evenly spaced and 2 for unevenly spaced data.

FSR REAL-VALUE HEADER (RHDR)

The real-value header is a 100-element floating-point array, written in lines 33-45 of the header, in format 8F10.3. The header is identical to the corresponding header for a Volume 2 file.

Line	Array Element	Description
33-45	1-100	Same as elements 1-100 of Volume 2 real-value header

Sample Even FSR File Listing for Turkey Flat experiment:

```
SPECTRAL RATIO WITH RESPECT TO REFERENCE STATION  R1 (CTF8)                      FOR
CORRECTED ACCELEROGRAM  R1 (CTF8)                      CHAN  1:  90 DEG    FROM  N
UNCORRECTED VELOCITY DATA                     PROCESSED: 05/18/88, CDMG EVENT12
TURKEY FLAT, USA, WEAK-MOTION TEST EVENT             STANDARD    GEOTECHNICAL MODEL
APRIL 26, 1988 18:29 PST                 (ORIGIN(USGS):  4/27/88,  2:29:25.29GMT)
WEAK-MOTION EVENT 12                TRIGGER TIME:  4/27/88,  2:29:30.80GMT
STATION NO. CTF8    35.878N, 120.361W    DR100  S/N  151 ( 3 CHNS OF  3 AT STA)
TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)     PREDICTION BY JOAN S. DOE
CHAN  1:  90 DEG  (STA CHN:  3)
COALINGA AREA EARTHQUAKE
HYPOCENTER(USGS): 36.183N,120.329W, H= 4KM.  ML=2.0(USGS).
INSTR PERIOD = 0.50   SEC,  DAMPING =  0.6 ,  SENSITIVITY = 104. V/M/S
                        RECORD LENGTH =  28.72 SEC.
                                     UNCOR MAX  =        G, AT          SEC.
RMS ACCEL OF (UNCOR) RECORD  =       G.
TWO POLE BUTTERWORTH BANDPASS FILTERED WITH CORNERS AT  1 AND 20 HZ.
FFT COMPUTED FROM WINDOW STARTING AT  6.741  SEC AND ENDING AT  14.741 SEC.
AMPLITUDE SPECTRA OF STATION AND REFERENCE SMOOTHED 2 TIMES
WITH A 11 POINT RUNNING MEAN FILTER BEFORE FORMING SPECTRAL RATIO.
SPECTRAL RATIO DATA BEGINS AT  1.000 HZ AND ENDS AT 20.000  HZ.
  194 POINTS OF SPECTRAL RATIO DATA AT EQUALLY-SPACED INTERVALS OF 0.09766  HZ.
COALINGA AREA EARTHQUAKE

WEAK-MOTION EVENT 12, TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)   CHAN  1:  90 DEG

    1    1    1    3    3    0    1    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0   90 2873   40   40   25    0
    0    0    0    0    0    0    0    1    0    0    0    0    0    0    0    0
    0    0 2873 2873 2873    0    0    0    0    0   25   80    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0
     0.500      0.600     28.720      0.000      0.000      0.000      0.000      0.000
     2.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
     0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
     0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
     0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
     0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
     0.000      0.000      0.000      0.000      0.000      0.000     12.566      0.000
     0.000      0.000      0.000      0.000      0.010      0.000      0.000      0.000
     7.840   -415.426      7.870      9.047     10.770     -0.353      0.007      0.000
     0.000      0.000     -0.002      0.000      0.000      0.000      0.000      0.000
     0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
     0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
     0.000      0.000      0.000      0.000
  194 POINTS OF SPECTRAL RATIO DATA EQUALLY SPACED AT 0.09766 SEC (UNITS: RATIO)
     1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
     1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
     1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
     1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
         ...
         ... (Remainder of acceleration data) ...
         ...
/&    <----- (End of data for this channel)
         ...
         ... (Header, etc for next channel)
         ...
         ...
```

Sample Uneven FSR File Listing for Turkey Flat experiment:

```
SPECTRAL RATIO WITH RESPECT TO REFERENCE STATION  R1 (CTF8)                  FOR
CORRECTED ACCELEROGRAM  R1 (CTF8)                    CHAN  1:  90 DEG     FROM N
UNCORRECTED VELOCITY DATA                      PROCESSED: 05/18/88, CDMG EVENT12
TURKEY FLAT, USA, WEAK-MOTION TEST EVENT             STANDARD   GEOTECHNICAL MODEL
APRIL 26, 1988 18:29 PST                    (ORIGIN(USGS):  4/27/88,  2:29:25.29GMT)
WEAK-MOTION EVENT 12                   TRIGGER TIME:  4/27/88,  2:29:30.80GMT
STATION NO. CTF8    35.878N, 120.361W     DR100  S/N  151 ( 3 CHNS OF  3 AT STA)
TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)      PREDICTION BY JOAN S. DOE
CHAN  1:  90 DEG  (STA CHN:  3)
COALINGA AREA EARTHQUAKE
HYPOCENTER(USGS): 36.183N,120.329W, H= 4KM.  ML=2.0(USGS).
INSTR PERIOD = 0.50   SEC,  DAMPING =  0.6 ,  SENSITIVITY = 104. V/M/S
                           RECORD LENGTH =  28.72 SEC.
                                          UNCOR MAX  =        G, AT          SEC.
RMS ACCEL OF (UNCOR) RECORD  =            G.
TWO POLE BUTTERWORTH BANDPASS FILTERED WITH CORNERS AT  1 AND 20 HZ.
FFT COMPUTED FROM WINDOW STARTING AT  6.741  SEC AND ENDING AT  14.741 SEC.
AMPLITUDE SPECTRA OF STATION AND REFERENCE SMOOTHED 2 TIMES
WITH A 1.074 HZ RUNNING MEAN FILTER BEFORE FORMING SPECTRAL RATIO.
SPECTRAL RATIO DATA BEGINS AT  1.000 HZ AND ENDS AT 20.000  HZ.
   77 POINTS OF SPECTRAL RATIO DATA AT UNEQUALLY-SPACED INTERVALS.
COALINGA AREA EARTHQUAKE

WEAK-MOTION EVENT 12, TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)   CHAN  1:  90 DEG

    1    1    1    3    3    0    1    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0   90 2873   40   40   25    0
    0    0    0    0    0    0    0    2    0    0    0    0    0    0    0    0
    0    0 2873 2873 2873    0    0    0    0    0   25   80    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0
     0.500     0.600    28.720     0.000     0.000     0.000     0.000     0.000
     2.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000    12.566     0.000
     0.000     0.000     0.000     0.000     0.010     0.000     0.000     0.000
     7.840  -415.426     7.870     9.047    10.770    -0.353     0.007     0.000
     0.000     0.000    -0.002     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000
   77 UNEVENLY SPACED FREQUENCY POINTS WHERE SPECTRAL RATIO HAS BEEN DETERMINED:
     1.270     1.660     1.855     1.953     2.246     2.637     2.832     2.930
     3.223     3.613     3.809     3.906     4.199     4.590     4.785     4.883
       ...
       ... (Remainder of frequency data) ...
       ...
     SPECTRAL RATIO CORRESPONDING TO ABOVE FREQUENCY POINTS IN UNITS OF RATIO:
     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
       ...
       ... (Remainder of spectral ratio data) ...
       ...
/&    <----- (End of data for this channel)
       ...
       ... (Header, etc for next channel)
       ...
       ...
```

STANDARD GEOTECHNICAL MODEL FOR THE TURKEY FLAT, USA SITE EFFECTS TEST AREA

Tables 1 and 2 summarize the geotechnical properties of the near surface geology at four site locations in the test area, where ground motion data are being acquired in an effort to validate methods of estimating the effects of local geology on earthquake ground motion for shallow stiff-soil sites. Figure 1 shows the locations of each site and three lines of profile. Figure 2 shows a cross sectional view along the three lines of profile to provide some knowledge of the three-dimensional structure of the test area.

The standard model was derived by a systematic procedure of data acquisition, analysis, and interpretation involving seven U.S. and two Japanese geotechnical firms and the California state government. Results of extensive field and laboratory tests, including state-of-the-art geophysical surveys, were selectively evaluated by members of an oversight committee of experts, leading to an average model of the test area that was reached by a consensus.

While this model represents a consensus of several experts in the geotechnical industry, it is not necessarily the most "accurate" model possible from the available data. Nonetheless, it serves as a standard against which various ground motion prediction methods can be compared with one another. For this reason each participant in the prediction phase of the experiment is being asked to make one set of predictions using this model. Investigators wishing to make additional predictions using their own alternative models based on the geotechnical data collected may do so at their own discretion. For this reason, individual geotechnical reports by each contributor are included in the appendices.

The remainder of this report provides a brief overview of the project, a more detailed description of the site characterization program, the regional geologic setting and local geology of the site, and a brief narrative on the geotechnical properties of the Turkey Flat Test Area.

Table 1A. Dynamic Soil Properties at Valley Center and Valley North (G-curve I).

% Shear Strain	G/Gmax	% Damping
10^{-4}	1.00	1.5
10^{-3}	0.96	2
10^{-2}	0.75	4
3×10^{-2}	0.60	6.5
10^{-1}	0.40	10
3×10^{-1}	0.22	13

Table 1B. Seismic Velocities at soil site Valley Center.

Depth Range (m)	Shear Wave Velocity (m/sec)	Compression Wave Velocity (m/sec)	Density (gm/cm^3)
0 - 2.4	135	320	1.50
2.4 - 7.6	460	975	1.80
7.6 - 21.3	610	975	1.90
Below 21.3	1340	2715	2.20

Table 1C. Seismic Velocities at soil site Valley North.

Depth Range (m)	Shear Wave Velocity (m/sec)	Compression Wave Velocity (m/sec)	Density (gm/cm^3)
0 - 2.1	150	305	1.55
2.1 - 5.5	275	915	1.75
5.5 - 11.0	610	975	1.90
Below 11.0	1340	2715	2.20

Table 2A. Dynamic Rock Properties at Rock South and Rock North (G-curve II).

Parameter	Value	Shear Strain
G/Gmax	1	all strain levels
Damping	1%	all strain levels

Table 2B. Seismic Velocities at Rock South and Rock North.

Depth Range (m)	Shear Wave Velocity (m/sec)	Compression Wave Velocity (m/sec)	Density (gm/cm^3)
0 - 2.4	825	1980	2.10
Below 2.4	1340	2715	2.20

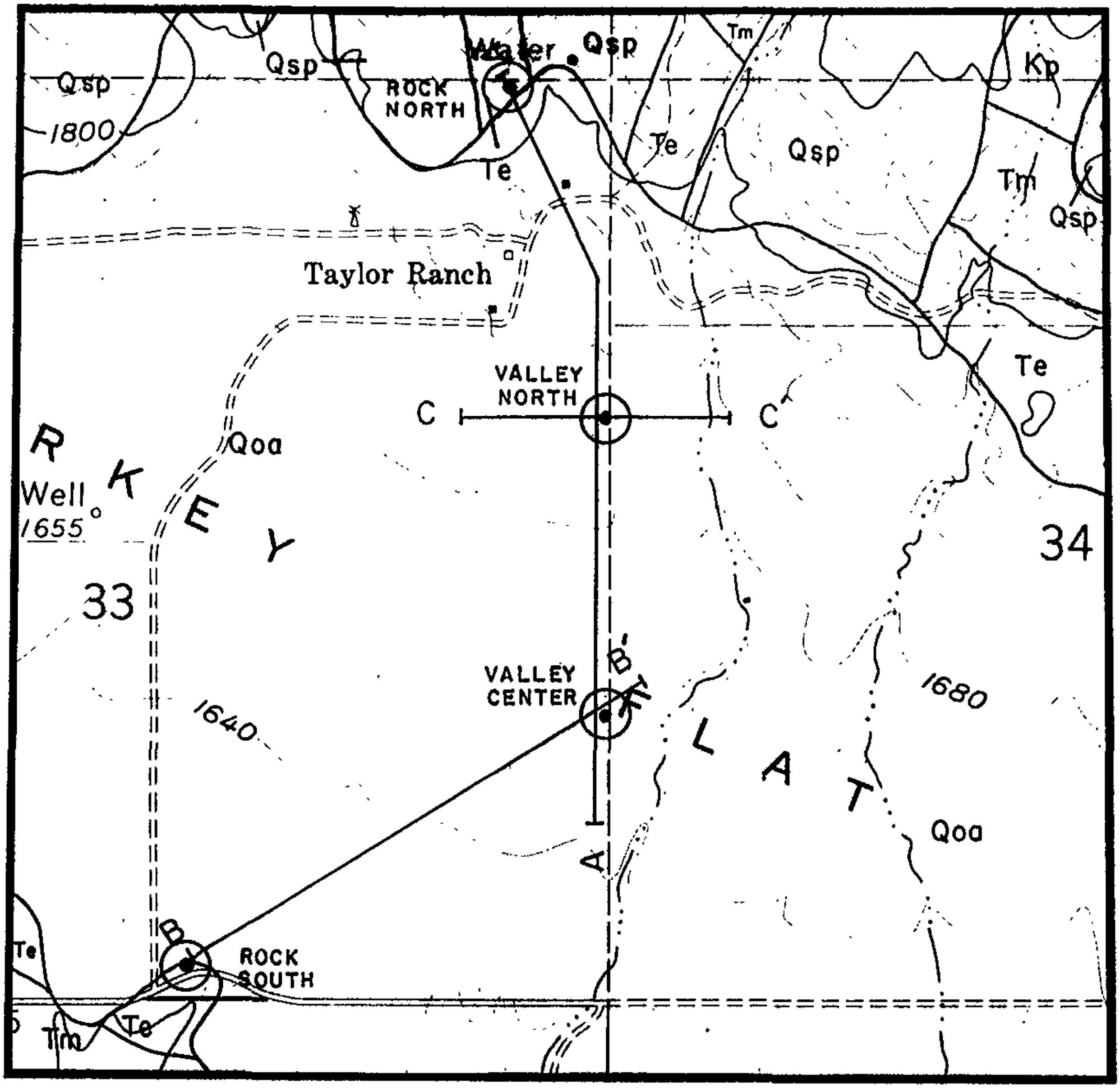
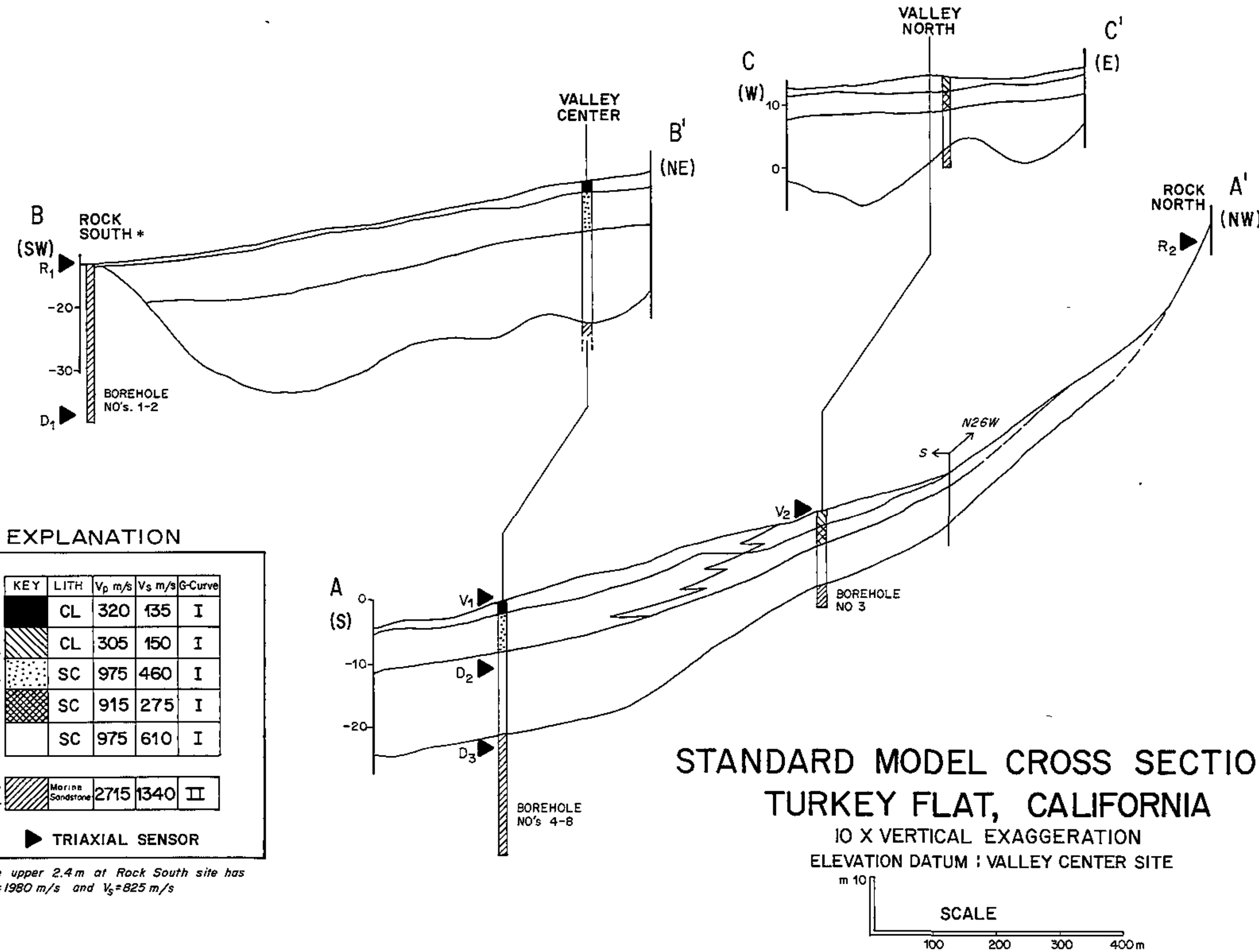


Figure 1. A map of the Turkey Flat Site Effects Test Area showing locations of the four ground motion recording sites, and three lines of profile that correspond to the cross sections shown in figure 2. At these locations, numerous geophysical surveys and laboratory testing of rock and soil samples have been conducted for the purpose of characterizing the test area for analysis of ground response. The remainder of this report describes the site characterization program and its findings in more detail.



STANDARD MODEL CROSS SECTIONS
TURKEY FLAT, CALIFORNIA

10 X VERTICAL EXAGGERATION

ELEVATION DATUM : VALLEY CENTER SITE

EXPLANATION

	KEY	LITH	V_p m/s	V_s m/s	G-Curve
Pleistocene Terrace Deposits (Qoa)		CL	320	135	I
		CL	305	150	I
		SC	975	460	I
		SC	915	275	I
		SC	975	610	I
Upper Pliocene (Tø)		Marine Sandstone	2715	1340	II

▶ TRIAXIAL SENSOR

Note: The upper 2.4 m at Rock South site has $V_p = 1980$ m/s and $V_s = 825$ m/s

FORMAT OF OBSERVED GROUND MOTIONS

When all of the prediction results have been received from the participants, the actual observed ground motions produced by the test event at each array site will be distributed so individuals can see how close their predictions come to reality. The observations will be distributed in standard Volume 2 and Volume 3 graphic output, and will be produced by the California Strong Motion Instrumentation Program (CSMIP). Observed ground motions will be presented in three plot types:

1) Instrument corrected acceleration, velocity, and displacement time histories;

2) Tri-partite response spectra showing pseudoacceleration, pseudovelocity, and absolute displacement, and;

3) Absolute acceleration.

Each type will be provided for <u>all three</u> components of ground motion at each array sensor location, even though the vertical component is not part of the prediction test.

An example of observed ground motion results for the test event as recorded at sensor location R1 is shown in figures 1-7.

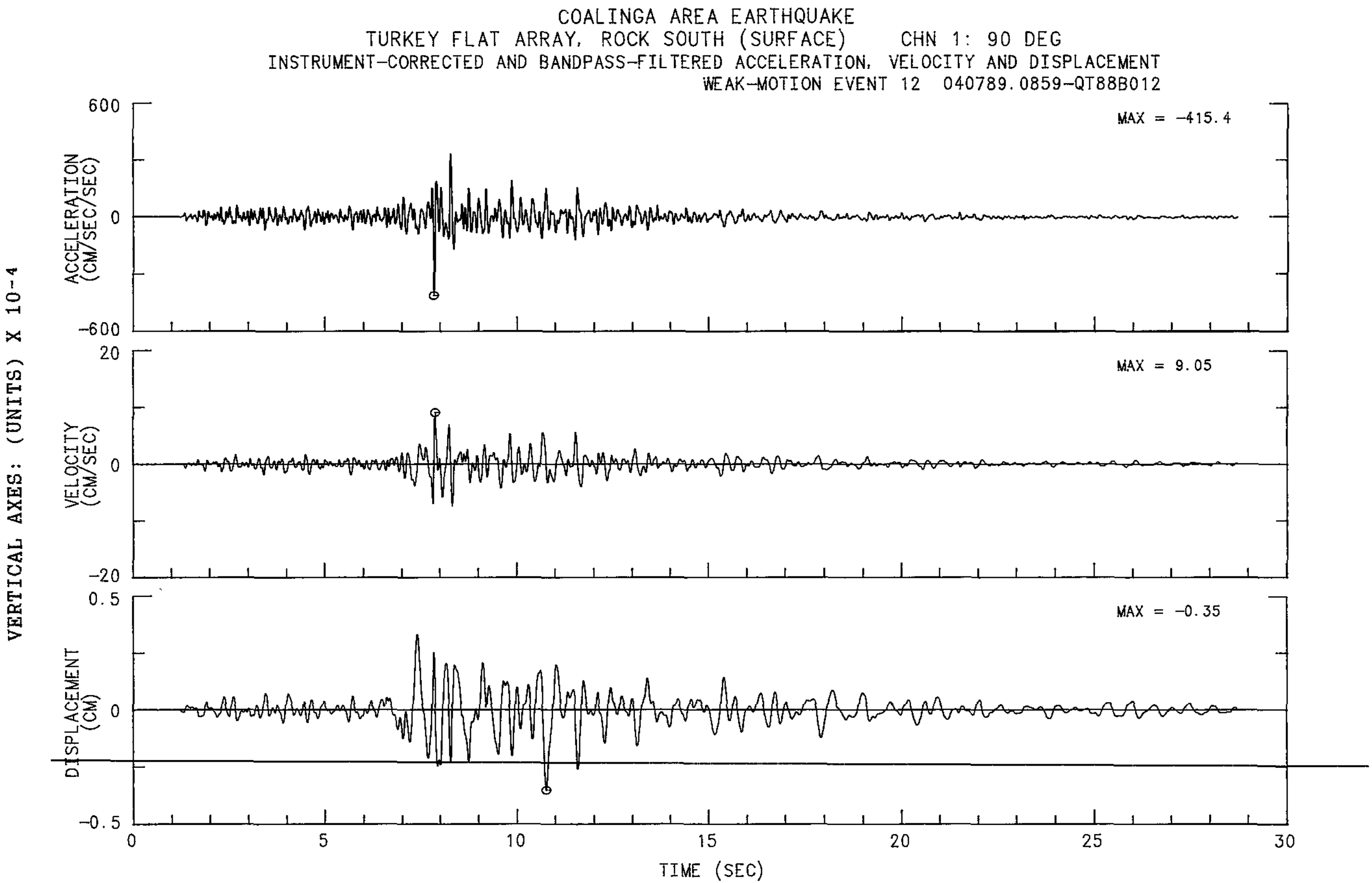

COALINGA AREA EARTHQUAKE
TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE) CHN 1: 90 DEG
INSTRUMENT-CORRECTED AND BANDPASS-FILTERED ACCELERATION, VELOCITY AND DISPLACEMENT
WEAK-MOTION EVENT 12 040789.0859-QT88B012
VERTICAL AXES: (UNITS) X 10-4
ACCELERATION (CM/SEC/SEC)
MAX = -415.4
600
0
-600
VELOCITY (CM/SEC)
MAX = 9.05
20
0
-20
DISPLACEMENT (CM)
MAX = -0.35
0.5
0
-0.5
0
5
10
15
20
25
30
TIME (SEC)

Figure 1

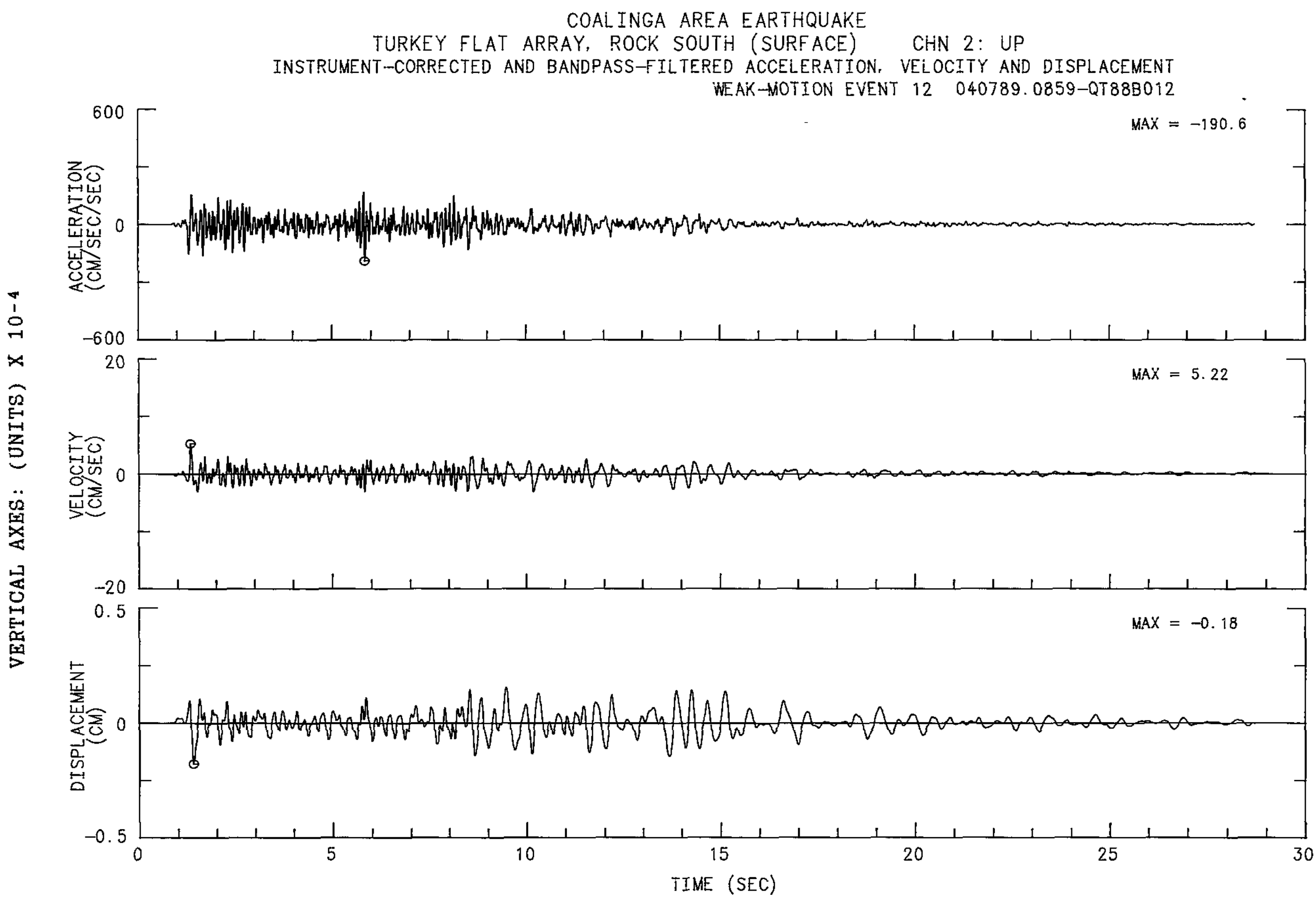

COALINGA AREA EARTHQUAKE
TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE) CHN 2: UP
INSTRUMENT-CORRECTED AND BANDPASS-FILTERED ACCELERATION, VELOCITY AND DISPLACEMENT
WEAK-MOTION EVENT 12 040789.0859-QT88B012
VERTICAL AXES: (UNITS) X 10-4
ACCELERATION (CM/SEC/SEC)
600
0
-600
MAX = -190.6
VELOCITY (CM/SEC)
20
0
-20
MAX = 5.22
DISPLACEMENT (CM)
0.5
0
-0.5
MAX = -0.18
0
5
10
15
20
25
30
TIME (SEC)

Figure 2

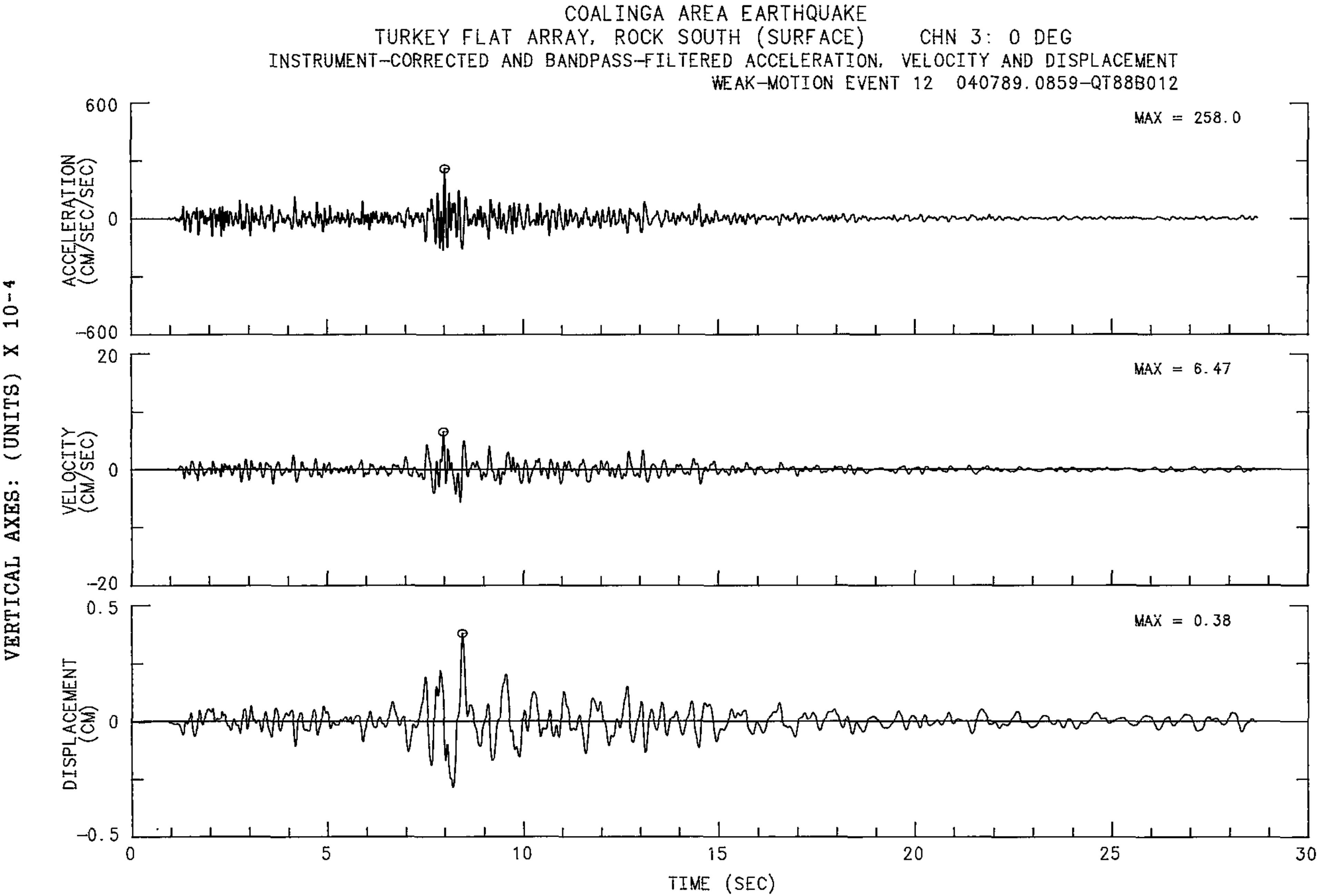

COALINGA AREA EARTHQUAKE
TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE) CHN 3: 0 DEG
INSTRUMENT-CORRECTED AND BANDPASS-FILTERED ACCELERATION, VELOCITY AND DISPLACEMENT
WEAK-MOTION EVENT 12 040789.0859-QT88B012
VERTICAL AXES: (UNITS) X 10-4
ACCELERATION (CM/SEC/SEC)
MAX = 258.0
VELOCITY (CM/SEC)
MAX = 6.47
DISPLACEMENT (CM)
MAX = 0.38
600
0
-600
20
0
-20
0.5
0
-0.5
0
5
10
15
20
25
30
TIME (SEC)

Figure 3

COALINGA AREA EARTHQUAKE
TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)
CHN 1: 90 DEG

WEAK-MOTION EVENT 12 040789.0920-QT88B012

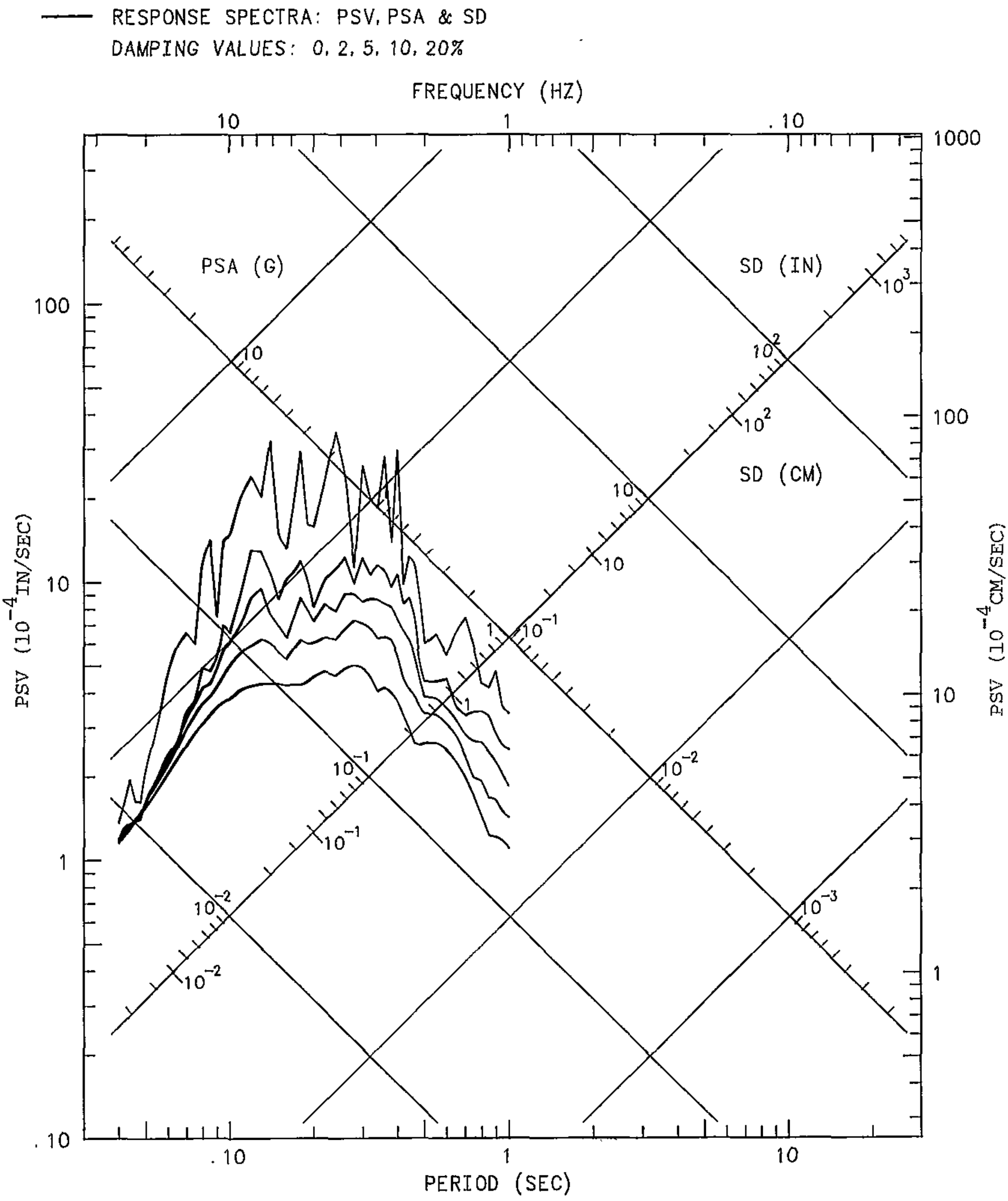


Figure 4

COALINGA AREA EARTHQUAKE
TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)
CHN 2: UP

WEAK-MOTION EVENT 12 040789.0920-QT88B012

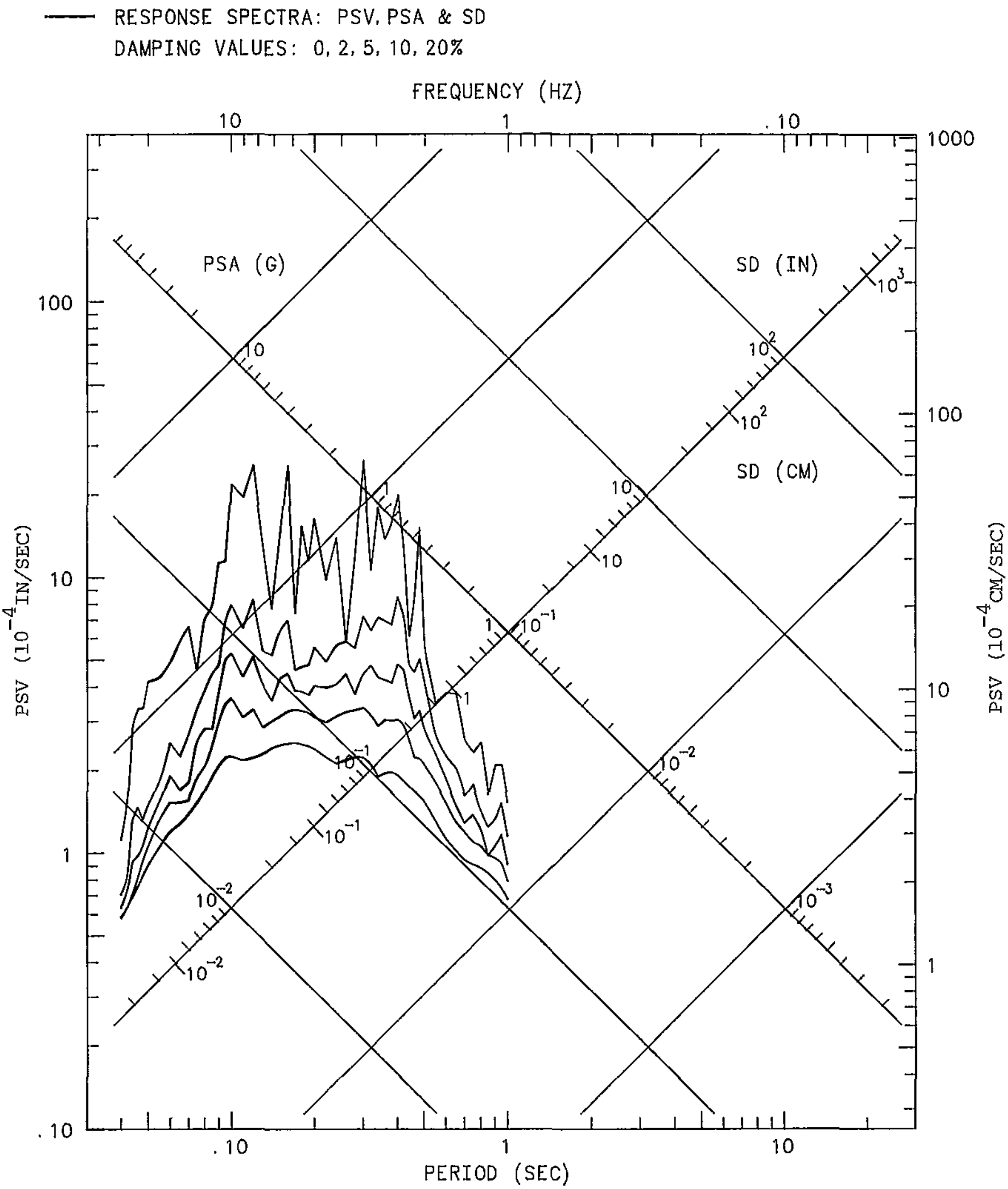


Figure 5

COALINGA AREA EARTHQUAKE
TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)
CHN 3: 0 DEG

WEAK-MOTION EVENT 12 040789.0920-QT88B012

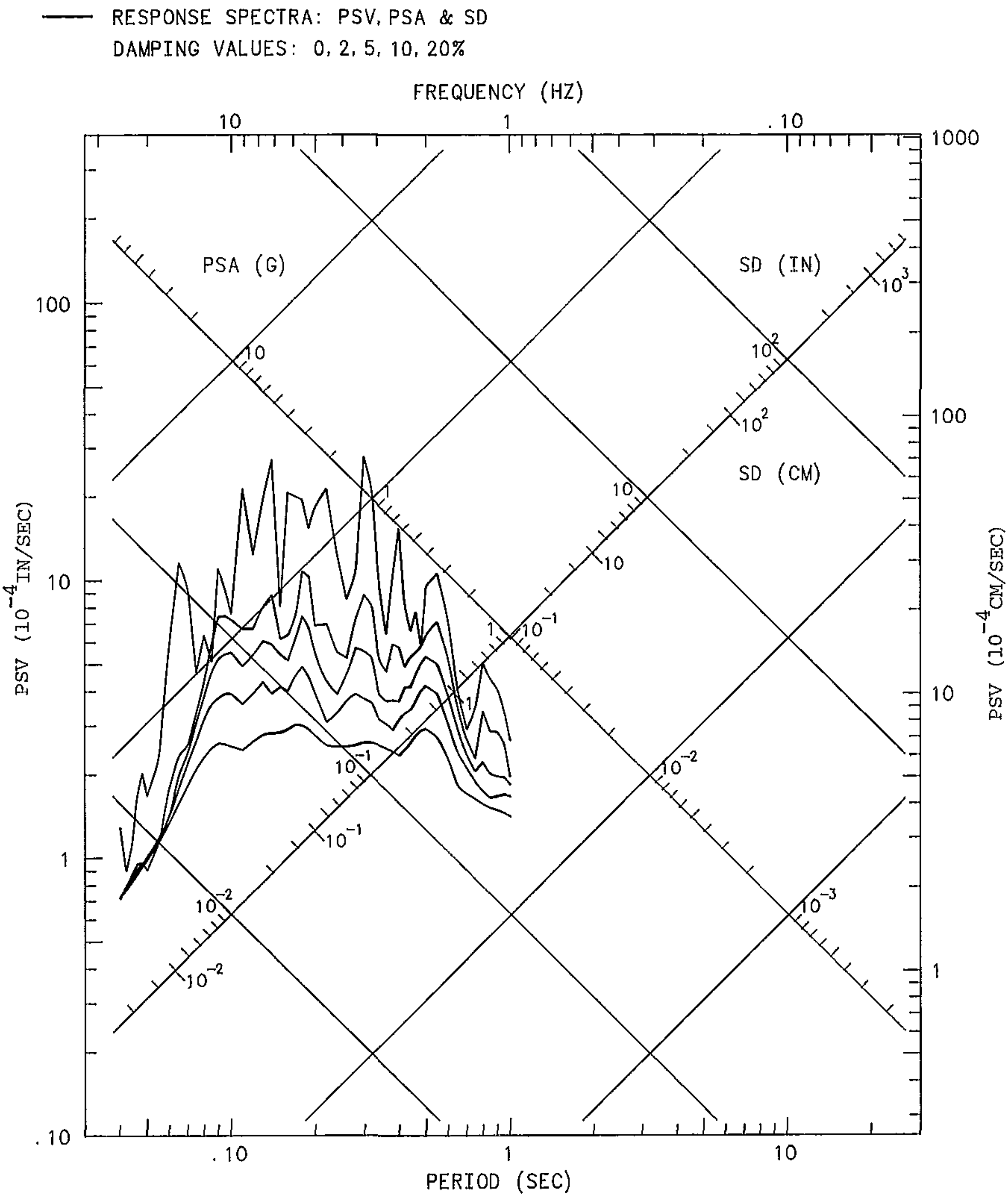


Figure 6

COALINGA AREA EARTHQUAKE
TURKEY FLAT ARRAY, ROCK SOUTH (SURFACE)

WEAK-MOTION EVENT 12 040789.0920-QT88B012

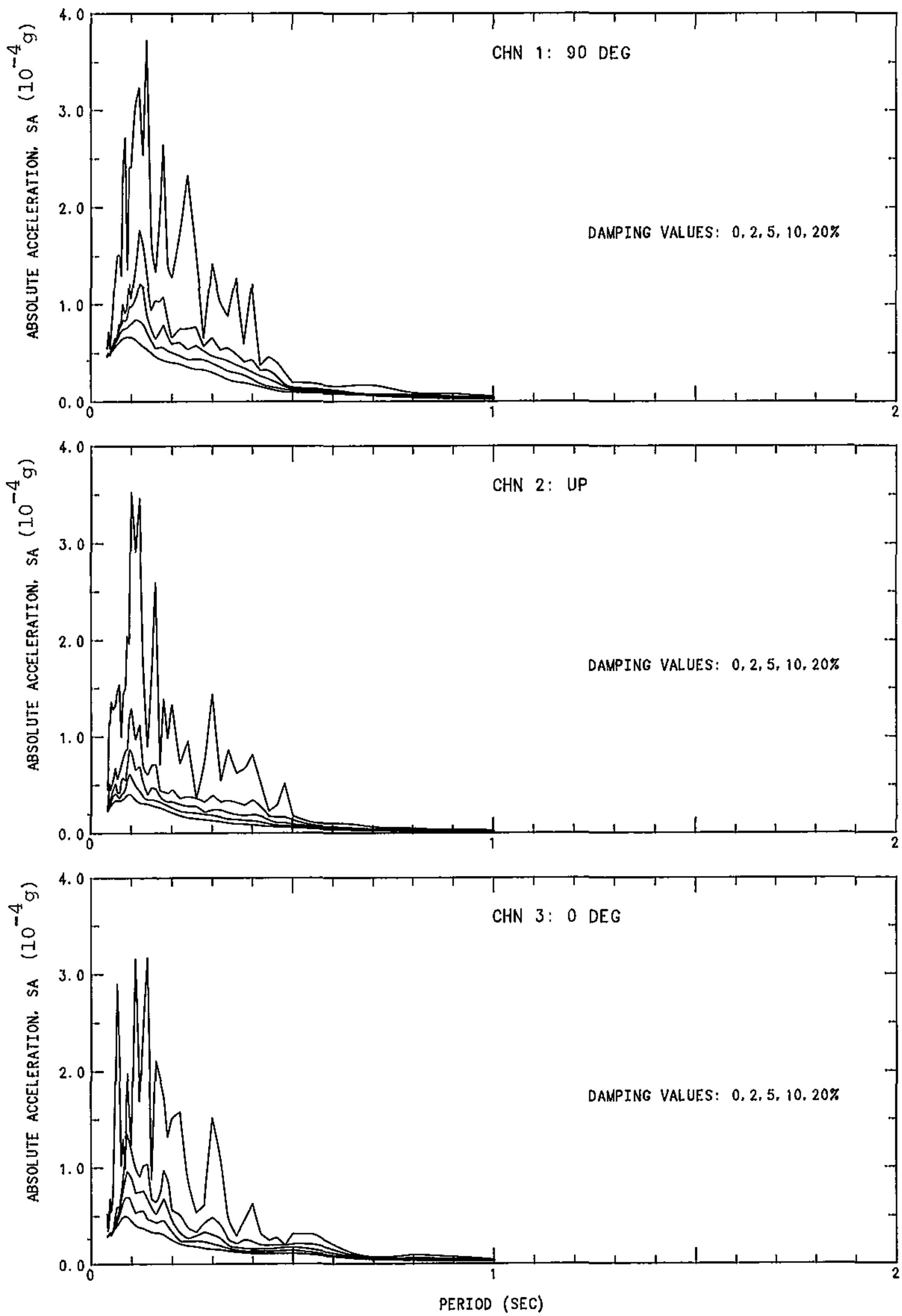


Figure 7